Abstracts 10,918-11,245

# SOLID STATE ABSTRACTS

*an abstract journal devoted to the theory, production and use of solid state materials and devices*

VOLUME 2 NUMBER 4

PHYSICS

METALLURGY

ELECTRONICS

SEMICONDUCTORS

PHOSPHORS

MAGNETICS

DIELECTRICS

SUPERCONDUCTORS

METALS

# SOLID STATE ABSTRACTS

VOLUME 2, NUMBER 4

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# ABSTRACTS OF THE SOLID STATE LITERATURE

## METALLURGY AND CHEMISTRY OF SOLIDS

### THERMODYNAMIC PROPERTIES OF ELEMENTS AND ALLOYS

10,918 INVESTIGATIONS OF BISMUTH TELLURIUM SULFUR COMPOUNDS by H. H. Soonpaa (Genl. Mills); U.S. Gov. Res. Rep., Vol. 35, p. 627 (A), May 16, 1961 PB 154 097

Compounds of the composition $Bi_2(Te,S)_3$ with the Te:S ratio ranging from 100:0 to 50:50 are studied. The single phase crystalline compound, $Bi_2(Te,S)_3$, with the Te:S ratio from 54:46 to 62:38, differs from the natural tetradymite. X-ray powder diffraction patterns were taken of all of the compounds prepared. The lattice constants, a and c, of the different $Bi_2(Te,S)_3$ compounds are compiled. A plot of the ratio of the intensities of the $2\theta_{110}$ and $2\theta_{0015}$ lines vs the composition revealed a sharp minimum at a Te:S ratio slightly above 58:42; a new compound corresponding to that composition was substantiated as $Bi_8Te_7S_5$. Two compounds resulting from the mixture of $Bi_2Te_3$ and $Bi_2S_3$ are believed to exist. The Hall mobilities and electrical conductivities of the samples seem to become very nearly the same at room temperature for $Bi_2Te_3$, and the 56:44 and 58:42 compounds.

10,919 THE PHASE DIAGRAM OF THE GALLIUM-TELLURIUM SYSTEM by P. C. Newman, J. C. Brice, and H. C. Wright (Philips); Philips Res. Rep., Vol. 16, pp. 41-50, Feb. 1961

Investigation of the phase diagram of the gallium-tellurium system by differential thermal analysis and direct observation of melting points under controlled tellurium pressures is reported. The results, which are confirmed by x-ray analysis, show that beside the two compounds already known (GaTe and $Ga_2Te_3$), there exist two other compounds, $Ga_3Te_2$ and $GaTe_3$. These two compounds, however, are not stable at room temperature. A hexagonal unit cell for $GaTe_3$ with a = 6.43 A and c = 14.20 A is reported. The melting points of GaTe and $Ga_2Te_3$ are 835 ± 2°C at $6.10^{-2}$ mm Hg Te-pressure and 792 ± 2°C at 2 mm Hg, respectively. Upper decomposition limits for $Ga_3Te_2$ and $GaTe_3$ are 753 ± 2°C and 429 ± 2°C.

10,920 TERNARY SYSTEM Th-Ce-Al by J. H. N. van Vucht (Philips); Philips Res. Rep., Vol. 16, pp. 1-40, Feb. 1961

The results of investigations into the ternary system Th-Ce-Al are reported. No ternary compounds were found. A review of data, in part published previously, regarding the binary systems Th-Al, Ce-Al and Th-Ce is included. Some data about the behavior of the element cerium are presented. The structure of a nonevaporating getter named Ceto, which prompted the investigations, is determined.

Solubility of Be in Ge - See 10,932

10,921 PHASE EQUILIBRIA AND TRANSFORMATIONS IN METALS UNDER PRESSURE by L. Kaufman (Mfg. Labs.); U.S. Gov. Res. Rep., Vol. 36, p. 117 (A), July 5, 1961 AD 255 892

High pressure effects on phase equilibria and transformations are considered from a thermodynamic point of view. The following conclusions are reached: (1) in most cases quantitative thermodynamic predictions at a level of accuracy and reliability comparable to current high pressure observations cannot be carried out; (2) in cases where the nature of the high pressure phase can be directly determined or inferred with some assurance, qualitative predictions of high pressure effects can be made by the proper utilization of one atmosphere thermodynamic data; and (3) the present considerations indicate that a reiterative combination of one atmosphere thermodynamic data with high pressure observations could lead to a greater understanding of phase transformations and equilibria in metals at one atmosphere and high pressure.

10,922 THERMAL PROPERTIES OF INDIUM by A. I. Kaznoff (U. California); U.S. Gov. Res. Rep., Vol. 36, p. 107 (A), July 5, 1961 AD 255 273

True heat capacity of high purity in (99.999 + per cent) was measured in the interval of 350 to 800°K. The high values of this thermodynamic property near the melting point (429.2°K) had the appearance of lambda-like transitions associated with higher order changes of state. The possibility of a phase transformation other than fusion was ruled out on the basis of measurements of electrical resistivity, transverse and longitudinal sonic velocities, and x-ray data. The process of fusion in In was identified as a first order transition from the pressure variation of the melting point. The effect of impurities and grain size on the pre-melting phenomena were shown to be minor. The results of electrical measurements were used as a check on the existence of phase transformation and to obtain the energy of formation of vacancies in In; this was found to be 5500 calories. The sharp decrease in the high heat capacity values for In near the melting point may indicate the break-down of clusters in the liquid. Since electrical resistivity measurements and ultrasonic measurements failed to indicate any abnormalities near the melting point, it is surmised that fractional crystallization may have occurred on the rough surface of the Mo crucible.

10,923 STUDY ON PRECIPITATION PHENOMENA IN THIN FILMS OF SUPERSATURATED GOLD-NICKEL ALLOY by Y. Fukano (Tohoku U.); J. Phys. Soc. Japan, Vol. 16, pp. 1195-1204, June 1961

The study of structure changes of supersaturated gold-nickel alloy after successive agings by means of electron diffraction and electron microscopy is discussed. Specimens were prepared by vacuum evaporation and subsequent quenching. After aging at temperatures lower than 165°C, side maxima appear beside the main spots from the matrix. The side maxima disappear after aging at 250-300°C, indicating that they correspond to preprecipitations. The side maxima are interpreted by assuming a modulated structure similar to that found in Au-Pt alloy by Tiedema et al. This implies that gold-nickel alloy at the preprecipitation stage contains a modulated structure similar to that in Au-Pt alloy. After aging at temperatures higher than 300°C, two stable phases with parallel lattices appear. In this state, Widmanstätten structure was found in electron micrographs.

## CRYSTAL STRUCTURE

Electron Beam Analysis of Insulating Crystals - See 10,973

10,924 STUDY OF THE TEXTURE OF THE BOUNDARY OF ETCHED AND GROUND REGIONS OF QUARTZ PLATE BY X-RAY DIFFRACTION by E. Fukushima and H. Nimura (Tokyo Metropolitan U.); J. Phys. Soc. Japan, Vol. 16, pp. 928-936, May 1961

The boundary effect, i.e., the anomalous enhancement of transmitted reflection from the boundary of the etched and ground regions of a quartz plate, is studied. By an x-ray photographic method, it is found that a fairly large strain is produced at the boundary and the strained layer extends to a deeper layer in the crystal than at the ground region. The influence of annealing on the boundary effect is also studied by a Bragg spectrometer. The anomalous enhancement is reduced by annealing at about 400°C. From the above results and some supplemental experiments on the ground surface, a model of the zone of strain at the boundary region is proposed and the mechanism of zone formation is considered.

X-Ray Analysis of BeO Crystals - See 10,954

10,925 222-REFLECTION FROM CuCl IN ELECTRON DIFFRACTION by F. Fujimoto (U. Tokyo); J. Phys. Soc. Japan, Vol. 16, pp. 936-943, May 1961

The (222) reflection of electron diffraction from CuCl is theoretically and experimentally studied. The ratio of the integrated intensity of the (222) reflection to that of the (111) reflection is calculated by expansion of the scattering matrix and by the solution of the Mathieu equation. Calculated results by both methods agree sufficiently with each other up to a grain size of 140 A for 41.3 kv electrons. The experimental values of the integrated intensity are found to be smaller than the theoretical values at small grain sizes of crystallites. However, it is confirmed that the ratio of integrated intensity of the (222) reflection to that of the (111) reflection is nearly proportional to the square of grain size and the wavelength, in qualitative accordance with theory. The (420) reflection is also measured dependence of the integrated intensity on wavelength is the same as that of the (222) reflection.

10,926 CRYSTAL STRUCTURE DISTORTIONS IN $MnO_2$ AND $MnF_2$ AT THEIR ANTIFERROMAGNETIC CURIE TEMPERATURE by S. L. Strong (U.S. Naval Ord. Lab. and MIT); J. Phys. Chem. Solids, Vol. 19, pp. 51-53, Apr. 1961

The changes in the lattice constants of $MnO_2$ and $MnF_2$ near the Néel temperature is discussed. It is found that on lowering the temperature the c-axis of $MnO_2$ expands while that of $MnF_2$ contracts. The results for $MnO_2$ and $MnF_2$, as well as other antiferromagnetics, indicate a correlation between the distortion and the spin direction, within a given crystal structure.

Lattice Constants of Compounds of $Bi_2(Te,S)_3$ - See 10,918

10,927 DETERMINATION OF THE MAXIMUM LATTICE-CHAIN ENERGY FROM SPUTTERING YIELD CURVES by D. E. Harrison, Jr. (U. Toledo); J. Appl. Phys., Vol. 32, pp. 924-927, May 1961

The determination of the maximum lattice-chain energy of metallic lattices by interpretation of sputtering yield curves is discussed. An analysis is presented which suggests that the "ankle energy," i.e., the energy at which the experimental sputtering ratio curve begins to form a low-energy tail, is the maximum energy which the metallic lattice can propagate in a close-packed direction. The effect appears to depend only upon the existence of a chaining threshold, and not upon the mathematical model of the sputtering process. The equivalence is demonstrated for the statistical model described, and for the primary lattice ion model of Kinchein and Pease.

Thermocyclic Behavior of Metals - See 10,960

10,928 MECHANISM FOR THE PRODUCTION OF INTERSTITIALS IN KCl BY X-RAYS AT LOW TEMPERATURES by R. E. Howard, S. H. Vosko, and R. Smoluchowski (Carnegie Inst. Tech.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 30 (A), Feb. 1, 1961

It was proposed that halogen vacancies and interstitials are formed in KCl by x-rays at low temperatures through multiple ionization of the halogen ions. The positive halogen ion collides with one of the neighboring negative ions forming a $Cl^+ Cl^-$ molecule. The repulsive state of a normal $Cl_2$ molecule intersects this state near its energy minimum and leads to a de-excitation exchange. This permits the conversion of the high electronic excitation energy into several ev of kinetic repulsive energy which is sufficient to form, by means of a series of focused collisions, a halogen vacancy (F center) and an interstitial (H center) a considerable distance away as required by experiment. The efficiency of multiple ionization (Auger effect) has been estimated and found to be in good agreement with the experiment.

Analysis of Dislocations in Cu - See 10,961

10,929 AN INVESTIGATION OF CRYSTAL IMPERFECTIONS BY X-RAY DIFFRACTION by A. R. Lang (Bristol U., England) U.S. Gov. Res. Rep., Vol. 36, p. 104 (A), July 5, 1961 AD 255 047

An investigation of Si sections that show a complex history of dislocation movement is discussed. Dislocation densities varie with distance from the crystal seed from 1000 to 100,000

lines sq/cm. Interference of dislocations belonging to 2 or more slip systems gives rise to tangles. Several other reactions between individual dislocations were analyzed. X-ray topographs were made of Ge crystals in the form of tapering wedges to study (1) the contrast of images as a function of thickness, (2) the modulation of intensity of diffracted beams as a function of thickness, and (3) the effect of surface irregularities. Crystals of InSb were examined with dislocation densities ranging from about zero to 10,000 lines sq/cm. Progress is reported in heat-treating, etching, and handling of LiF. X-ray topographs of quartz show localized regions of enhanced reflecting power. Work was continued on extending and developing a basic theory of refraction of energy flow and a new approach to the diffraction theory of a distorted crystal.

10,930 ROLE OF SURFACES IN PLASTIC FLOW OF ROCK-SALT SINGLE CRYSTALS by S. Mendelson (Columbia U.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 281 (A), Apr. 24, 1961

Direct observations of dislocations moving in plastic flow from the center of a surface to opposite edges of a NaCl crystal was discussed. Sharp slip steps were observed on the surface of well-prepared small crystals. Dislocation pileups were not found against the nascent surface but were found against an ozonized surface. It was found that the initially active sources lie close to or on the surface. Ozonization of NaCl surfaces for short periods restricts the action of surface sources, and for longer times provides barriers to the egress of dislocations. The Suzuki effect (formation of a work-hardened surface layer) was found to depend upon the existence of a multiplicity of surface sources such as is produced by polishing on wet silk. Cross-slip of screw dislocations at the surface under the image force was found to be greater when the specimen is polished during or after the formation of glide bands. This effect was proposed as the likely mechanism to explain the "Joffe effect" when atmospheric variables are eliminated.

Zone Strain Model for Quartz - See 10,924

Effect of H on Displacement Threshold of Irradiated Ge - See 10,965

10,931 ANALYSIS OF TRACE IMPURITIES IN SILICON CARBIDE by R. Rupp and G. Morrison (Genl. Tel. Electronics); U.S. Gov. Res. Rep., Vol. 35, p. 627 (A), May 16, 1961 PB 153 682

The development of three direct spectrographic methods for the determination of ultratrace impurities in high purity SiC and Ni, and for the determination of traces of boron in Si is described. The methods are two or three times more sensitive than previous methods. A technical manual describing the procedure for the determination of impurities in SiC is included.

Measurement of Oxygen in Silicon by Ion Drift Techniques - See 10,992

Determination of $I^-$ in KCl:I Crystals - See 11,046

10,932 THE DIFFUSION OF BERYLLIUM IN GERMANIUM by Yu. I. Belyaev and V. A. Zhidkov (Lenin State U.); Soviet Phys.-Solid State, Vol. 3, pp. 133-134, July 1961

Measurement of the coefficient of diffusion D and the solubility of beryllium in germanium at temperatures ranging from 720 to 920°C is discussed. It was found that $D = 0.5 \exp(-2.5/kT)$ and that in the indicated temperature interval $c_0$ is a function of temperature.

10,933 DIFFUSION OF ANTIMONY IN GERMANIUM ALLOYED WITH ALUMINUM by I. P. Akimchenko and L. S. Milevskii (Boikov Metall. Inst.); Soviet Phys.-Solid State, Vol. 2, pp. 1891-1896, Mar. 1961

The diffusion coefficient, D, of antimony between 650 and 930°C as a function of the concentration, n, of aluminum in germanium is discussed. Four values for n were chosen between $2.4 \times 10^{14}$ and $3 \times 10^{18}$ $cm^{-3}$, inclusive. Initially, D increases with n until the latter reaches approximately $5 \times 10^{17}$ $cm^{-3}$. Thereafter, D decreases with increasing n, in qualitative agreement with the vacancy mechanism of diffusion. The temperature dependence of D for each value of n is determined, as well as the variation of D as a function of n, at several fixed temperatures.

10,934 COEFFICIENTS OF SELF-DIFFUSION IN ALLOYS by B. Ya. Pines and I. V. Smushkov (Khar'kov State U.); Soviet Phys.-Solid State, Vol. 3, pp. 105-109, July 1961

The coefficient of diffusion of atoms of one of the components into the alloy and the coefficient of self-diffusion of "average" atoms of the alloy as a function of the composition of the alloy are calculated. The relationships obtained include the so-called coefficients of activity $f_i$. Regular solutions are investigated as approximations.

10,935 SELF-DIFFUSION OF THE CHLORIDE ION IN SODIUM CHLORIDE by N. Laurance (Illinois U.); U.S. Gov. Res. Rep., Vol. 35, p. 551 (A), May 16, 1961 PB 152 884

The self-diffusion coefficient of the chloride ion in pure NaCl crystals and in NaCl crystals doped with $CaCl_2$ is evaluated. The measured diffusion coefficient can be expressed as $D = 56.6 \exp(-2.12 \text{ ev}/kT)$ between 520°C and 740°C for pure NaCl, and $D = 1280 \exp(-2.49 \text{ ev}/kT)$ between 585°C and 730°C for NaCl crystals containing 0.05 mole per cent calcium. The diffusion coefficient of chlorine has been measured isothermally as a function of calcium concentration. The results are not expressible by a simple relation, but they indicate that the diffusion coefficient is lower in crystals containing calcium than in pure crystals by a factor of from 5 to 10, and that the diffusion coefficient is insensitive to the magnitude of the calcium concentration. It is concluded that the motion of free negative ion vacancies, while adequate to explain the observed diffusion coefficient in the case of pure crystals, fails to explain the observed dependence of the diffusion coefficient on calcium concentration. The motion of vacancy pairs is examined as a mechanism for diffusion, and it is concluded that unless the theoretical treatment of the vacancy pair has been grossly inadequate the observed temperature dependence of the diffusion coefficient of chlorine in both pure and doped crystals precludes the motion of vacancy pairs as a possible mechanism of diffusion. The details of the penetration of the isotope into the crystal exclude any effects due to dislocation lines which are long compared to the penetration distance.

10,936 SELF-DIFFUSION IN SILVER DURING PLASTIC DEFORMATION IN TORSION by J. B. Darby, Jr. (Argonne Natl. Lab.), C. T. Tomizuka (U. Arizona), and R. W. Balluffi (U. Illinois); J. Appl. Phys., Vol. 32, pp. 840-848, May 1961

Studies of self-diffusion of $Ag^{110}$ in Ag polycrystals subjected to

simultaneous torsion near 700° and 800°C are described. Strains $\leq 0.50$ and strain rates $\leq 13.8 \times 10^{-5}$ sec$^{-1}$ were employed. Specimen structures before and after deformation were also examined. The effects of straining on diffusion were relatively small in all cases. At 800°C the diffusivity was increased by no more than ~50 per cent; at 700°C the increase was no more than ~100 per cent. A substantial part of this observed enhancement was undoubtedly only apparent and due to difficulties associated with surface roughness. The results agree generally with our previous work involving deformation in extension and compression, but were in marked disagreement with recent results of Lee and Maddin, and Forestieri and Girifalco, who have reported enhancements larger by one to two orders of magnitude. No simple explanation for these differences was found. Estimates of dislocation short-circuiting and the generation of extra point defects indicate that only small enhancements should be expected, in agreement with the present results.

10,937 ANODIC SECTIONING OF DIFFUSED SILICON P-N JUNCTIONS by B. McDonald and F. C. Collins (Shockley); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 106 (A), Mar. 20, 1961

The diffusion profile of a p-n junction was studied. The method described by Schmidt for anodic oxidation of Si was used to section the junction. Thickness of removed layers of Si was determined by careful weighing on a microbalance and was found to be consistent on successive runs at constant current density. Diffused layers of 0.5-μ junction depth were sectioned in such a manner, conductivity measurements made after each sectioning, and from these the diffusion profile was studied. The results indicated that the impurity distribution did not follow the expected error function dependence.

## CRYSTAL GROWTH

10,938 THE PREPARATION AND PROPERTIES OF SOME II-V SEMICONDUCTING COMPOUNDS by G. A. Silvey, V. J. Lyons, and J. V. Silvestri (IBM); J. Electrochem. Soc., Vol. 108, pp. 653-658, July 1961

Methods of purification and single crystal growth of six II-V semiconducting compounds are discussed and crystallographic data are presented. The six compounds, representing three stoichiometries, are $Cd_3As_2$, $CdAs_2$, CdSb, $Zn_3As_2$, $ZnAs_2$, and ZnSb. The compounds are thermally dissociated in the vapor phase, and the solid-vapor equilibria of four of the compounds has been measured. Because of the thermal instability, crystal pulling was carried out in sealed quartz tubes, employing magnetic suspension of the seed. Through purification of the elements and single crystal growth, high purity was attained in most of the compounds. The highest purity is represented in $CdAs_2$ with an electron carrier concentration of $5 \times 10^{14}$ cm$^{-3}$.

10,939 PRODUCTION OF MONO-CRYSTAL SEMI-CONDUCTOR BODIES by J. L. Parmee (Brit. Thomson-Houston); U.S. Pat. 2,981,687, Issued Apr. 25, 1961

A method for producing single crystals of Ge or Si minimizing contamination resulting from physical contact between a molten zone and its container, is discussed. A pellet containing a desired amount of dopant is placed on the surface of an ingot of substantially pure semiconductor material, and localized melting of that surface and the pellet forms a relatively small molten zone. (The pellet is unnecessary if the melted end of the ingot already contains the desired amount of dopant.) A seed crystal then makes contact with the surface of the zone. The ingot is progressively melted as the seed crystal is withdrawn, carrying with it the frozen single crystal of uniform resistivity. The structure and operation of the furnace are described.

Growth of $Bi_2S_3$ Crystals, Dendrites, and Films - See 10,974

Preparation of Ferrites by Sintering - See 11,020

10,940 FERROMAGNETIC MATERIAL by E. W. Gorter, G. H. Jonker, H. P. J. Wijn, and J. A. Schulkes (Philips); U.S. Pat. 2,977,312, Issued Mar. 28, 1961

The preparation of ferromagnetic compounds which have frequency-independent initial permeability and low magnetic losses up to 200 Mc is discussed. The ferromagnetics have the composition $Ba_{(3-a-b-c)}Sr_aPb_bCa_cMe^{II}{}_{(2-d)}Co_dFe_{24}O_{41}$ in which $Me^{II}$ is $Mn^{II}$, $Fe^{II}$, $Ni^{II}$, $Cu^{II}$, $Zn^{II}$, or $Mg^{II}$ and the metal complex $\frac{Li^{I} + Fe^{III}}{2}$ and a varies from 0 to 1, b varies from 0.6, c varies from 0 to 0.3, and d is less than 2. The materials have a hexagonal crystal structure with c = 52.3 A and a = 5.9 A. The ferromagnetic compounds are prepared by presintering a finely powdered mixture of the components, grinding the resulting product and re-sintering it. The sintering is performed at between 1000°C and 1400°C, preferably between 1200°C and 1350°C.

10,941 GROWTH OF SINGLE-CRYSTAL IRON FERRITES BY THE CZOCHRALSKI METHOD by F. H. Horn (GE Res. Lab.); J. Appl. Phys., Vol. 32, pp. 900-901, May 1961

The growth of pure single crystals of ferrites by the Czochralski method is discussed. Iridium crucibles are used without attack. The use of heat reflectors overcomes the oxidation of the grown crystals by $CO_2$. A drawing of a satisfactory furnace for growing ferrite crystals is shown. Using "Specpure" oxides, it is necessary to heat the grown magnetite crystals in a $CO$-$CO_2$ atmosphere at appropriate temperatures to obtain crystals of acceptable stoichiometry.

10,942 MAGNETIC IMPULSE RECORD CARRIER by W. Harz and R. Bruck (Agfa); U.S. Pat. 2,978,414, Issued Apr. 4, 1961

The preparation of ferromagnetic iron-cobalt oxide powders which have remanence values between 400 and 650 gauss and coercivity values between 220 and 420 oe is discussed. Hydroxides of cobalt and iron are precipitated from an aqueous solution containing water soluble salts of iron and cobalt. The precipitation is carried out in the temperature range 5°-30°C. The precipitate is converted to ferromagnetic iron-cobalt oxides by treating the precipitate with an alkaline agent in the presence of an oxidizing agent in the temperature range 65°-90°C. The oxides are separated from the aqueous solution and, if necessary, the dried oxides are heated in an oxidizing gaseous atmosphere at 200°-350°C. The resulting ferromagnetic oxides contain 1.5 - 4 atomic per cent of cobalt and 5-15 atomic per cent of trivalent iron. The incorporation of the oxides in a non-magnetic binder on a non-magnetic tape, wire, disc, Fiber, or Foil is discussed.

10,943 HIGH-ENERGY MAGNETIC MATERIAL by T. O. Paine, L. I. Mendelsohn, and F. E. Luborsky (GE); U.S. Pat. 2,974,104, Issued Mar. 7, 1961

The production of elongated, single domain ferromagnetic particles with very large coercive force is described. Iron particles of this type can be prepared by electrodepositing iron from a $FeCl_2$ electrolyte into a pure liquid Hg cathode. The process is performed without the electroplating bath undergoing any motion whatsoever. An iron ingot is used as the cathode. Iron-mercury slurries are removed from the cathode with a magnet. The slurries are heat-treated in air, mixed together, and coated with tin. Pressure is applied to the slurries in the presence of a magnetic field. The resulting material is suitable for use in magnets. Material containing 44 per cent iron by volume with a coercive force of 650 oe, a residual flux density of 7150 oe, and a BH product of $2.02 \times 10^6$ gauss-oe has been produced.

10,944 MAGNETIC CERAMIC FIBERS AND METHOD OF MAKING SAME by H. B. Whitehurst (Owens-Corning Fiberglass); U.S. Pat. 2,968,622, Issued Jan. 17, 1961

The production of ferromagnetic ceramic fibers is discussed. A molten mixture of ferromagnetic material and glass is forced through a cooled orifice, about which is applied a magnetic field, to form a continuous flexible fiber. The forces exerted on the material during the fiber-forming process cause an alignment of the magnetic domains in the fiber. The application of a magnetic field to fibers which undergo devitrification during the fiber-forming process as the fiber leaves the orifice also results in the desired alignment of magnetic domains. Magnetic alignment is produced in those fibers which do not undergo devitrification during the fiber-forming process by subsequently heating them to a temperature which causes devitrification in the presence of a magnetic field.

Preparation of Ferromagnetic Films by Electrodeposition - See 11,016

Preparation of Co Films - See 11,018

10,945 STUDIES ON MAGNETOSTRICTIVE FERRITES by G. S. Smith (Curtiss-Wright); U.S. Gov. Res. Rep., Vol. 35, p. 626 (A), May 16, 1961 PB 154 095

The reproducibility of the properties of magnetostrictive ferrites and the changes in the properties brought about by small changes in composition are discussed. The study is concerned primarily with a correlation of properties with particle size and distribution of the raw and reacted oxides as influenced by chemical composition and the forming and firing variables. The basic compositions studied were:

$$NiO \cdot Fe_2O_3 \text{ and } NiO_{(1-a)} \cdot CoO_{(a)} \cdot Fe_2O_3.$$

Since the properties of the ferrites varied uniformly as the average particle size of the presintered powder, it was concluded that the physical state of the presintered material must be controlled in order to assure a high degree of reproducibility. Two compositions of $NiO \cdot Fe_2O_3$ which had average particle sizes of 1.52 and 1.55 μ were prepared to demonstrate the effect that particle size and firing schedule have on the properties. The samples were fired separately at 1400°C for 1 hour. The maximum variations were: density of ±0.02 per cent; resonant frequency ±0.01 per cent, electromechanical coupling of 0 ± 0.75 per cent; and mechanical Q of ± 1.5 per cent.

10,946 FERROMAGNETIC CERAMIC MATERIALS by C. L. Guillaud, A. Pierrot, and Y. C. Lescroel (Ctr. Natl. Réch. Sci.); U.S. Pat. 2,977,311, Issued Mar. 28, 1961

A technique for reducing the temperature coefficient of initial permeability in Mn-Zn ferrites over a wide temperature range is discussed. The permeability is reduced by replacing part of the ferric oxide with aluminum oxide. A decrease in the Curie point proportional to the concentration of aluminum oxide occurs. The preparation of several different compositions by this technique is described.

10,947 FERROMAGNETIC MATERIAL FOR GYROMAGNETIC EFFECT by C. L. Guillaud and R. Vautier (Ctr. Natl. de la Réch. Sci., Paris); U.S. Pat. 2,980,618, Issued Apr. 18, 1961

Compositions of ferrites which possess a gyromagnetic effect are discussed. The basic structure contains (in molar per cent) 18 NiO, 32 ZnO, and 50 $Fe_2O_3$; compositional ranges are listed. Chromic oxide ($Cr_2O_3$), substituted for $Fe_2O_3$ in the range between 2 and 20 per cent, increases the efficiency of the ferrite in a gyromagnetic application. The angle of rotation in the plane of polarization and the attenuation are both plotted as a function of the $Cr_2O_3$ content. The preparation and evaluation of seven ferrites within the disclosed compositional ranges are described.

10,948 MANGANESE ZINC FERRITE CONTAINING TUNGSTIC OXIDE by K. Wetzel (Steatite Res.); U.S. Pat. 2,980,619, Issued Apr. 18, 1961

The inclusion of from 0.1 to 1.0 per cent by weight of the equivalent of tungstic oxide ($WO_3$) in the formulation of Mn-Zn ferrites to obtain high saturation flux density is described. A saturation flux density at room temperature of greater than 5500 gauss, B, at 25 oe, H, is reported. The components are fired at 1300° to 1400°C, in a protective atmosphere. Compositional ranges for all components and a detailed description of the process are presented.

10,949 FERRITE COMPOSITIONS AND METHOD OF MAKING SAME by J. R. Ireland (Indiana Genl.); U.S. Pat. 2,980,617, Issued Apr. 18, 1961

Ferrites which possess high coercive force and maximum energy product without substantial effect on the residual induction are described. Compositions involve partial substitution of ferric ion by Ba, Sr, or Pb, and inclusion of a small amount of a refractory ceramic such as kaolin ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$) or mullite ($3Al_2O_3 \cdot 2SiO_2$). In preparation, the sintering conditions are said to be less critical than in current manufacturing procedures. Permanent magnet ferrites having energy product maxima exceeding $3 \times 10^6$ gauss-oe were prepared, the high value being related to an increased coercive force at a given residual induction.

10,950 SQUARE LOOP FERRITES by E. Albers-Schoenberg (Steatite Res.); U.S. Pat. 2,981,689, Issued Apr. 25, 1961

Square loop ferrites for application in computer and magnetic memory systems are described. The desirable properties include high squareness ratio (over 0.8), high differential permeability, sharp corners on the hysteresis curve, relatively high saturation flux density, and relatively low coercive force. Some compositions within the ranges listed produce low values of saturation flux density, a requirement for some computer systems. The body is an Mn-Mg ferrite; the compositional range is described by an area within the system bounded by 8 to 55 per cent mag-

nesia, 4 to 67 per cent manganese oxide, and from 25 to about 47.5 per cent ferric oxide. Variation in performance characteristics as a function of composition is discussed.

10,951 FERRITES WITH SQUARE HYSTERESIS LOOPS by E. Albers-Schoenberg (Steatite Res.); U.S. Pat. 2,981,690, Issued Apr. 25, 1961

The formulation and operating characteristics of ferrites having square hysteresis loops are described. The composition range is an area within the system MO-MnO-$Fe_2O_3$, where MO is a mixture of two or more oxides. The area is bounded by mol percentages of 4 to 25 MO, 27.5 to 66 MnO, and 30 to 47.5 $Fe_2O_3$. MO may consist of the oxides of Mg (2 per cent or more), Ca, Zn, and Cu. Characteristics imparted by each MO are listed, permitting compositional choice to achieve a specific operating property endpoint. The parameters of saturation, remanence, coercive force, initial and maximum permeability for 10 compositions are compiled.

Preparation of Dense $ZrO_2$ by Hydrostatic Pressing - See 10,980

10,952 GROWTH AND DISSOLUTION PROCESSES OF GASH CRYSTAL by T. Nakamura, K. Ohi, and H. Kubota (Ochanomizu U.); J. Phys. Soc. Japan, Vol. 16, pp. 906-912, May 1961

The growing process of GASH (Guanidine Aluminum Sulfate Hexahydrate) crystals is described. If a droplet of saturated GASH solution on a glass slide is heated from above, the platelets obtained which float on the drop show six-rayed-star-shaped terraces. The mechanism of terrace formation is ascribed to the bunching of progressing atomic steps. On the other hand, if the slide is heated from below, some large, thick platelets obtained at the bottom of the droplet show dislocation etch pits on etching, while others remain small and thin, showing no pits on etching. It appears that the growing process is not diffusion-controlled but follows the screw dislocation mechanism. Dissolution of GASH crystals occurs by progression of macroscopic steps, which are nucleated both at crystal edges and dislocation emergence points. The kinetics is controlled by diffusion.

10,953 SYNTHETIC MICA CRYSTAL GROWTH PROGRAM by J. G. Froemel, E. C. Worden, and P. S. Hessinger (Synthetic Mica); U.S. Gov. Res. Rep., Vol. 35, p. 630 (A), May 16, 1961 PB 154 515

A plant-scale progressive melt, composition control experiments, and other studies, all involving the growth of synthetic mica crystals, are described. Mica crystal growth theory is discussed, and the initial design of a laboratory crystal growing apparatus is presented. The experimental work being conducted on solution growth is described and a comprehensive bibliography of synthetic mica references is included.

Growth of Single Crystals of $ZrO_2$ - See 10,980

10,954 THE OXIDATION OF POLYCRYSTALLINE BERYLLIUM IN CARBON DIOXIDE by W. J. van Peer (Austl. AEC); Austl. J. Phys., Vol. 4, pp. 191-192 (L), Mar. 1961

The preferred orientation and grain size of BeO crystals grown on heated samples of polycrystalline Be are discussed. The specimens of Be were heated to 700°C in an atmosphere of $CO_2$. It was determined that preferred (001) oriented BeO crystals appeared after treatment at 700°C, and that these grew with large faces parallel to the Be substrate. No beryllium carbide rings appeared in the diffraction patterns obtained in diffraction studies.

## CRYSTAL SURFACES

Oxide Formation on CdTe and ZnTe Surfaces - See 11,011

10,955 IONIZATION METHOD FOR STUDYING THE KINETICS OF ADSORPTION PROCESSES ON THE SURFACES OF SOLID BODIES by Ya. P. Zingerman and V. A. Morozovskii (Phys. Inst., Kiev); Soviet Phys.-Solid State, Vol. 3, pp. 88-94, July 1961

A new experimental method for the investigation of the processes of adsorption on and desorption from surfaces of solid bodies, which is based upon intensity measurements of atomic beams after they are ionized by electron impacts, is described. The method makes it possible to carry out complex measurements of rates of adsorption and desorption, of heats of evaporation, of coefficients of condensation, of surface concentrations of condensed atoms, and finally, of changes in the electronic properties of adsorbed films. The possibilities offered by the method are illustrated by an example of its application to the study of adsorption of atoms of beryllium on tungsten.

10,956 POLISHING TECHNIQUE FOR GARNET SPHERES by A. L. Pierce (Stanford Res. Inst.); IRE Trans., Vol. MTT-9, pp. 266-267 (L), May 1961

The final stages of polishing yttrium-iron-garnet spheres using a motor-driven polishing head is reported. The process has produced several fractional oersted linewidth crystals, including a matched-pair of 0.060-in diam spheres, ground simultaneously. The process consists of lowering a motor-driven rotating pad, lined with a polishing cloth into a similarly-lined dish containing the sphere until contact with the sphere is made. A magnet is located beneath the dish. The formation of a uniform surface is formed by the circular motion of the polishing head combined with the alignment of the sphere, caused by the sphere's preference to change direction to an easy crystal axis of magnetization.

10,957 NEW ELECTROCHEMICAL TECHNIQUE FOR POLISHING SEMICONDUCTOR WAFERS; Bell Labs. Rec., Vol. 39, p. 107, Mar. 1961

A new electrochemical technique for rapid, scratch-free polishing of Ge and Si wafers for transistors is described. The new polishing method is considered to be much faster and more efficient than conventional polishing methods, and no damage is introduced during processing.

10,958 CAPILLARY ALLOYING: AN IMPROVED ALLOYING METHOD by K. Lehovec, K. Busen, J. Casey, C. Pochop, and A. Webb (Sprague Elect.); J. Electrochem. Soc., Vol. 108, p. 241, Mar. 1961

The preparation of uniformly alloyed small metallic contacts to semiconductors is discussed. The method utilizes a liquid alloy contained in a capillary and fed from a large reservoir of alloy. It is demonstrated that extremely flat junctions can be prepared and that the distance of these junctions from the wafer surface can be controlled at as shallow a depth as 0.25 μ. Advantages

of this new method include very high degree of purity of the liquid alloy surface previous to alloying, the possibility of investigating conveniently a large number of alloy compositions, and avoiding the handling of extremely small pellets. The diffusion constant of Ge in liquid In is found to be $D = 4.9 \times 10^{-5}$ $cm^2/sec$.

10,959 CRYSTAL-SUPPORT ASSEMBLY AND METHOD OF FORMING SAME by B. V. Lawson (Philco); U.S. Pat. 2,980,829 Issued Apr. 18, 1961

A method of forming a mechanically strong, low-ohmic, contact to crystals which are adversely affected by high temperature soldering is described. A metal is alloyed into the crystal to provide a low-ohmic region upon which a stud is positioned. The low-ohmic region and the stud are joined with an electroformed bond by an electroplating procedure. A specific example involving a gallium arsenide crystal is cited.

## ENVIRONMENTAL EFFECTS

Effects of Annealing on Au-Ni Alloys - See 10,923

Recovery of Resistivity in Au by Low Temperature Anneal - See 10,994

Effect of Quenching on the Minority Carrier Lifetime in Ge and Si - See 10,989

10,960 INVESTIGATIONS CONCERNING THE THERMOCYCLIC BEHAVIOR OF METALS [in German] by W. Epprecht (AFIE, Zurich); NT, Vol. 3, pp. 269-287, May 1961

The dimensional changes caused by heat cycling specimens of An, Bi, and In of random texture are discussed. For cycling entirely below the temperature of recrystallization, $T_R$, the stresses cause slipping and twinning within the crystals, and cracks may appear. The work-hardening gradually stops the motions so that further cycles do not result in new deformations. Therefore, the total dimensional changes remain small. For cycling partially or completely above $T_R$, however, the gliding crystals soften with each cycle. Moreover, those crystals with an unfavorable slip-orientation retain rigidity below $T_R$, but are deformed at temperatures near or above $T_R$ by a mechanism related to the so-called polygonization. The mutual relations between the grains which are deformed only at high temperatures (polygonizing grains) and those that can glide during the whole cycle (gliding crystals) result in a considerable deformation which does not stop during continuous cycling.

High Pressure Effects on Metals - See 10,921

10,961 EFFECT OF NEUTRON IRRADIATION ON THE PLASTIC DEFORMATION OF COPPER SINGLE CRYSTALS by I. G. Greenfield and H. G. F. Wilsdorf (Franklin Inst. Labs.); J. Appl. Phys., Vol. 32, pp. 827-839, May 1961

The examination after plastic deformation, of Cu single crystals subjected to a neutron dose of $3 \times 10^{18}$ nvt (total flux) at pile temperature is described. The experimental techniques include observation of the load-extension relationships, investigation of the slip-line structure with the electron microscope, and diffraction electron microscopy of thinned-down single crystals before and after deformation. The critical resolved yield stress is in the order of 1.6 $kg/mm^2$.

10,962 STRESS FIELD CAUSED BY SLIP IN A WORK-HARDENING CRYSTAL IN AN AGGREGATE by T. H. Lin and D. Martin (California U.); U.S. Gov. Res. Rep., Vol. 35, p. 626 (A), May 16, 1961 PB 153 729

The stress field of an aggregate of randomly-oriented crystals loaded just beyond the elastic limit is computed. The elastic modulus of each crystal is taken to be isotropic. The sliding directions and planes of different crystals are different. The initial stage of plastic deformation, at which only the most favorably oriented crystal slides, is considered. This sliding crystal is assumed to be of cubic shape and at the interior of a fine grained aggregate. The aggregate is infinitely large as compared to the crystal. It is shown that the plastic strain gradient is equivalent to body force in the calculation of stress field. The equivalent body force caused by slips in the sliding crystal is considered to apply in an infinite elastic isotropic medium. The known solution of the stress field caused by a concentrated force in an infinite medium is applied to express the stress components in terms of slip distributions in the sliding crystal. The increase of critical shear stress with slip caused by work hardening is considered. The resolved shear stress is equated to this critical shear stress in the sliding region, providing an integral equation in terms of slips at different points. This equation is solved numerically by the method of finite difference. The stresses caused by these slips are then calculated and shown in graphs. These stresses caused by slips decrease rapidly with the distance from the sliding crystal.

Self-Diffusion in Ag During Plastic Deformation in Torsion - See 10,936

Spin Resonances in Irradiated $\alpha$-$Al_2O_3$ - See 11,008

10,963 PARAMAGNETIC RESONANCE INVESTIGATION OF ATOMIC HYDROGEN AND TRITIUM IN NEUTRON-IRRADIATED CRYSTALLINE FLUORIDES by J. A. Dweck and P. J. Bray (Brown U.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 113 (A), Mar. 20, 1961

The electron-spin paramagnetic resonances of atomic hydrogen and tritium at room temperature in neutron-irradiated crystalline fluorides were evaluated. In LiF, tritium is a product of the disintegration of $Li^6$ nuclei via the reaction $Li^6(n,\alpha)H^3$. The atomic hydrogen presumably results from the breakup of OH radicals present in the crystals. The observed electron spin resonance doublets may be identified by their characteristic g value and splittings of $543.2 \pm 0.1$ and $508.6 \pm 0.1$ gauss for tritium and hydrogen, respectively. Both have linewidths of about 2 gauss. From the structure of the individual hyperfine components, some insight into the positions of the hydrogen and tritium atoms in the lattice and their interactions with the neighboring lattice atoms may be gained. The dependence of the spectra on post-irradiation thermal treatment was discussed.

10,964 RADIATION DAMAGE IN CRYSTALLINE FLUORIDES by C. D. Knutson, R. Kaplan, and P. J. Bray (Brown U.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 113 (A), Mar. 20, 1961

Neutron irradiation damage in single crystals of $CaF_2$ and NaF was investigated. The investigation utilized the techniques of nuclear magnetic resonance (NMR) and electron-spin paramagnetic resonance (ESPR). Data for LiF were previously reported but were included. Under certain conditions it has been found that pile irradiation produces colloidal metal and molecular fluorine within the lattices of these materials. NMR measurements of the gaseous fluorine in all three compounds yield the

fractions of these materials present in the lattice after irradiation. Information concerning the configuration of the colloidal sodium in irradiated NaF has been obtained both from NMR measurements and from observation of the ESPR of conduction electrons in the sodium metal.

Production of Interstitials in KCl by X-Rays - See 10,928

10,965 EFFECT OF HYDROGEN ON THE DISPLACEMENT PROCESS IN Ge by J. A. Naber and H. J. James (Purdue U.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 303 (A), Apr. 24, 1961

An hypothesis for the low-energy irradiation effects in Ge, in which the electron bombardment displacement threshold is less than 360 kev, was discussed. The hypothesis evolves upon the concentration of hydrogen atoms in Ge crystals. It was stated that these "below threshold" effects might be due to displacement of Ge atoms resulting from a two-step process in which the electron initially strikes a hydrogen atom which then collides with a lattice atom. The maximum energy transferred to the Ge atom in the two-step process is four times that for a direct electron-Ge collision; thus the threshold for producing a displacement by the two-step process should be about 100 kev. An order of magnitude calculation indicates that in the presence of $10^{18}$ hydrogen atoms/$cm^3$ there will be about $10^{-6}$ displaced Ge atoms/cm/incident electron at 300 kev. Comparison of irradiations of crystals grown in a hydrogen atmosphere with crystals grown in a vacuum shows that hydrogen-grown crystals have conductivity changes consistent with the above calculations, while vacuum-grown crystals are essentially unaffected by "below threshold" irradiation. The results suggest that the two-step hypothesis is a likely explanation of the low-energy irradiation effects in Ge.

10,966 STORED ENERGY IN X-IRRADIATED SODIUM CHLORIDE by F. T. Phelps and E. A. Pearlstein (U. Nebraska); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 114 (A), Mar. 20, 1961

The change in the heat of solution of NaCl caused by x-irradiation is evaluated. The method consists of preparing two identical samples, irradiating one with 140 kv x-rays and recording its ultraviolet and visible spectra, dissolving both in water in a differential calorimeter, and measuring the temperature difference. The experiment has been carried out for a number of F-center densities between 2.4 and 6.4 x $10^{17}$ F-centers/$cm^3$. In this range, a plot of stored energy vs F-center concentration is a straight line with slope of about 8.8 ev/F-center. At 2.6 x $10^{17}$ centers/$cm^3$ the average stored energy per center is about 3.2 ev.

10,967 OBSERVATION OF LATTICE DEFECTS IN FISSION FRAGMENT-IRRADIATED GRAPHITE by K. Izui and F. Fujita (Japan Atomic Energy Res. Inst.); J. Phys. Soc. Japan, Vol. 16, pp. 1032-1033 (L), May 1961

Electron microscopic observations of large defects in graphite induced by fission fragment irradiation are presented. Refined powder of natural graphite, mixed with uranium oxide powder in the ratio 10:1, was exposed to thermal neutrons of the order of $10^{16}$ n/$cm^2$. A concentric fringe pattern is shown representing a large damaged region where the lattice is buckled due to the spike effect producing a number of atomic displacements. A second photo shows a highly damaged region represented by many concentric fringe patterns and their complex couplings. A third photo shows dislocation lines, having become more rugged and changed in contrast, after irradiation.

10,968 ELECTRON MICROSCOPE STUDY OF RADIATION DAMAGE IN GRAPHITE by W. Bollmann (Battelle Mem. Inst.); J. Appl. Phys., Vol. 32, pp. 869-876, May 1961

The application of dark-field transmission electron microscopy to the study of defects in neutron-irradiated graphite is discussed. The annealing is followed, and the appearance of the defects is interpreted on the basis of the kinematical theory of electron diffraction. A physical interpretation of the observations based on displacement spikes and their annealing is given

Sputtering Yields of Metals - See 10,927

10,969 INVESTIGATION OF THE SPUTTERING OF SILICON by S. P. Wolsky and E. J. Zdanuk (Raytheon); J. Appl. Phys., Vol. 32, pp. 782-786, May 1961

The sputtering yields for the argon-silicon system over an energy range of 34 - 800 ev are determined. Variation of the discharge voltage provides information on the relative sputtering effectiveness of $Ar^+$ and $Ar^{2+}$ ions. Extrapolation of the low-energy data indicates a probable threshold energy of 15-20 ev. The sputtering data indicate that the target surfaces were clean and reproducible. The experimental method is shown to be well suited for sputtering studies. Preliminary data for the ion bombardment of Si with $CO_2$ are also presented.

10,970 MERCURY ION BEAM SPUTTERING OF METALS AT ENERGIES 4-15 KEV by G. K. Wehner and D. Rosenberg (Genl. Mills); J. Appl. Phys., Vol. 32, pp. 887-890, May 1961

Sputtering yields of metals for normally incident $Hg^+$ ions at energies between 4 - 15 kev are measured. Fourteen metals from the 4th, 5th, and 6th periods are studied. The sputtering rate is determined by measuring the time required for the ion beam to pierce a target foil. Results for the various metals show that yields at high energy behave similarly to yields previously found at lower ion energy; i.e., are closely linked to the position of the metal in the periodic chart. Yields increase in the 4th period from Ti through V, Fe, Co, Ni to Cu and in a similar fashion in the 5th period to Ag and in the 6th period to Au. It is believed that Cu, Ag, and Au atoms, with their more closely filled d shells, behave more nearly like hard spheres and always produce the highest sputtering yields.

10,971 RECOVERY OF ELECTRON RADIATION DAMAGE IN N-TYPE InSb by F. H. Eisen (Atomics Intl.); Phys. Rev., Vol. 123, pp. 736-744, Aug. 1, 1961

Studies of the production and recovery of electron radiation damage in n-type InSb by means of Hall-coefficient and electrical-conductivity measurements are reported and discussed. Irradiations were performed mainly at 80°K, since no recovery was observed between 4° and 80°K. The damage recovered in five well-defined stages with the recovery nearly complete at 320°K. Isochronal and isothermal recovery was monitored in each of the stages, allowing a determination of the activation energies for recovery and a study of the recovery kinetics. None of the recovery kinetics fit any simple models. There is evidence that two lowest-temperature recovery stages involve the annihilation of close interstitial-vacancy pairs and that interactions of primary defects with impurities do not occur. However, the first-order kinetics expected for close-pair recovery is not explicitly observed. A possible explanation for the ob-

served kinetics, involving the independent annihilation of two types of close-pair configurations in the same stage with an electrostatic interaction between the interstitial and vacancy, is proposed.

10,972 LOW TEMPERATURE ANNEALING OF ELECTRON-BOMBARDED Ge by E. E. Klontz and J. W. MacKay (Purdue U.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 303 (A), Apr. 24, 1961

The relative recovery in each of the two stages in low temperature annealing of electron-bombarded Ge was discussed. The lower stage, about 35°K, was associated with recombination of closest stable vacancy-interstitial pairs; the upper stage, about 64°K, was associated with next-closest pairs. The relative amount of annealing in each of these temperature ranges depends on the total flux which the sample receives. For fluxes less than $10^{16}$ electrons/cm$^2$, no appreciable annealing occurs in the 35°K stage. For more than $10^{17}$ electrons/cm$^2$, about half of the recovery is in each stage. These results indicate that the 35°K stage is probably not associated with primary defects. For sufficiently small irradiation, so that the 35°K stage is not observed, it is found that the per cent recovery in the 64°K stage varies with the bombardment energy, from about 10 per cent for 600 kev electrons to about 50 per cent for 1.0 Mev and above. This is consistent with results showing the existence of radiation annealing which is relatively more important at lower energies.

10,973 INTERACTION OF SLOW ELECTRONS WITH INSULATING CRYSTALS. Part I. ABSORPTION COEFFICIENT FOR CLEAVED ALKALI HALIDES; EXPERIMENTAL TECHNIQUES by C. J. Cook and W. J. Fredericks (Stanford Res. Inst.); J. Appl. Phys., Vol. 32, pp. 860-866, May 1961

Techniques permitting a unique determination of an absorption coefficient, $\delta_a$, for 0.2 to 20-ev electrons on cleaved, insulating crystals are developed. Pure and nonstoichiometric KBr and KCl crystals are studied. Two classes of electron trapping levels, one that empties rapidly and one that does not empty at room temperature, may exist in the target and thereby perturb the data. Experimental techniques which compensate for each characteristic effect are described. The probability that a crystal-incident electron results in a charge influx is found to vary markedly as a function of the impact energy and in a manner characteristic of the target. This feasibility study indicates that slow electron beams could be a powerful tool for diagnosing surface and bulk properties of insulating crystals.

Electron Bombardment Damage in Si Esaki Diodes - See 11,077

# SOLID STATE PHYSICS

## GENERAL

10,974 SOME SEMICONDUCTING PROPERTIES OF BISMUTH TRISULFIDE by L. Gildart, J. M. Kline, and D. M. Mattox (U. Kentucky); J. Phys. Chem. Solids, Vol. 18, pp. 286-289, Mar. 1961

Single crystals, dendrites, and crystalline films of bismuth trisulfide, $Bi_2S_3$, have been prepared and studied. From the films a thermal energy gap of 0.72 ev is found in the range 300 - 400°K. From the single crystals, optical energy gaps of 1.4 ev at 77°K, and 1.2 ev at 300°K, are found. Resistivity, carrier concentration and mobility at 300°K are 0.85 ohm-cm, $3 \times 10^{17}$ cm$^{-3}$ and 50 cm$^2$/volt-sec, respectively. Thermal conductivity and Seebeck coefficient are found to be 0.0206 w/cm°C and 550 μv/°C for single crystal samples in a direction parallel to the principal cleavage planes at 300°K. Preparation techniques and the apparatus used in the thermal conductivity and Seebeck coefficient measurements are described.

## CRYSTAL PHYSICS
## (Including Energy Band Structure)

10,975 ANHARMONIC CORRECTIONS TO VIBRATIONAL THERMODYNAMIC PROPERTIES OF SOLIDS. Part I. THE HIGH TEMPERATURE LIMIT by R. A. Coldwell-Horsfall (U. Maryland), P. A. Flinn, and A. A. Maradudin (Westinghouse Res. Labs.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 119 (A), Mar. 20, 1961

Cubic and quartic anharmonic corrections to the Helmholtz free energy of a crystal derived as functions of temperature for a general force constant model of the crystal were cited. The resulting expressions are evaluated in the high temperature limit for the case of a fcc lattice with nearest-neighbor central force interactions between atoms. These results are then applied to the calculation of the high-temperature anharmonic corrections to the specific heat at constant volume and to the thermal expansion.

10,976 GENERALIZED KOOPMANS' THEOREM by J. C. Phillips (U. Chicago); Phys. Rev., Vol. 123, pp. 420-424, July 15, 1961

An alternative approach to effective single particle Hamiltonians based on an extension of Koopman's derivation of the Hartree-Fock Hamiltonian is presented. The method is developed to clarify the relationship between many-electron and one-electron wave functions and is preferable to the quasi-particle formalism. Koopman's theorem is generalized to include correlation effects by using Hubbard's expression for the total energy of a free-electron gas. Hubbard's lowest polarization diagram gives part of the screened second-order Coulomb interactions, which is small for metallic densities. Collective terms are also obtained. Comparison with the Bohm-Pines Hamiltonian shows a one-to-one correspondence, but with different cut-off functions in each term. Following Hubbard, the method is extended to include the effects of a periodic potential to first order. The resulting one-electron Hamiltonian provides a convenient and accurate basis for self-consistent energy band calculations including exchange and correlation in metals and semiconductors.

10,977 SELECTION RULES CONNECTING DIFFERENT POINTS IN THE BRILLOUIN ZONE by J. J. Hopfield and M. Lax (Bell Labs.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, pp. 108-109 (A), Mar. 20, 1961

Selection rules for indirect radiative transitions and for intervalley scattering were investigated for Ge and Si. Comparison with experimental results of Haynes and of Aigrain supports (1) present picture of the band structure of Ge with a conduction band minimum at the zone boundary, (2) the assignment of $L_2'$

as the symmetry of the LA phonon at the zone boundary in the 111 direction. The absence of the LA phonon in the Haynes radiative emission experiment still requires explanation. To obtain the required selection rules we take the product of two irreducible representations i and j that belong to different wave vectors k and k'. The resulting character product is expressed in a form appropriate to a third group $G_{k''}$ at $k'' = k + k'$. If the elements of $G_{k''}$ are applied to k to generate a star and N(C) is the number of points of the star invariant (or equivalent) under any element R in the class C (of $G_{k''}$) then the character product is $N(C) < \chi^i(R)\, \chi^j(R) >_C$, i.e., N(C) times the product of the characters averaged over those R in C which belong to $G_{k'}$ and $G_{k''}$ (i.e., those whose characters can be found in the tables at k' and k'').

10,978 SPIN-ORBIT SPLITTING IN ZnCd:S SINGLE CRYSTALS by D. C. Reynolds and C. W. Litton (Aeronautical Res. Lab.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 111 (A), Mar. 20, 1961

The spin-orbit splitting in both CdS and ZnS yielding values of 0.016 and 0.026 ev, respectively, was discussed. These values were obtained at liquid $N_2$ temperature. Single ZnCd:S crystals have been grown from the vapor phase and an approximately linear relationship between band gap and anion concentration was reported. Spin-orbit splittings have been determined from reflection measurements on crystals containing up to 20 per cent Zn in CdS and on crystals containing up to 7 per cent Cd in ZnS. Spin-orbit splittings have not as yet been observed in crystals containing higher concentrations than those mentioned above. It is believed that inhomogeneities in the higher concentrations cause an energy spread in the band edges over finite distances in the crystal and the reflection peaks are "washed" out. The spin orbit splittings in the mixed crystals vary nonlinearly between the values observed in CdS and those obtained in ZnS.

10,979 ELECTRONIC ENERGY BANDS IN CsAu by V. E. Wood (Battelle Mem. Inst.) and J. R. Reitz (Case Inst. Tech.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 108(A), Mar. 20, 1961

Valence and conduction electron energy bands in CsAu were computed using the cellular method, with the radial parts of the wave functions determined by the quantum defect method. CsAu is assumed to be completely ionic. The results indicate that CsAu is a semiconductor, as found experimentally, with a minimum energy gap, which is vertical, of about 2.3 ev located at the extremum of the <111> direction in the first zone.

## ELECTRICAL PROPERTIES

### DIELECTRIC PROPERTIES

10,980 THE ELECTRICAL BEHAVIOR OF REFRACTORY OXIDES by R. W. Vest (Systems Res. Labs.); U.S. Gov. Res. Rep., Vol. 36, p. 64 (A), July 5, 1961 AD 255 079

A study on the production and the electrical properties of refractory oxides is discussed. Preliminary work has been done on the preparation of dense $ZrO_2$ by hydrostatic pressing (4000 to 17,000 psi) and sintering in vacuum at 1800 to 1950°C. An attempt will be made to grow single crystals from the vapor phase of the reaction between $ZrCl_4$ and oxygen near 1000°C. Details of an experimental apparatus for the measurement of electrical conductivity, dielectric constant, and thermoelectric power are presented.

10,981 DIELECTRIC CONSTANT WITH LOCAL FIELD EFFECTS INCLUDED by N. Wiser (U. Chicago); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 119 (A), Mar. 20, 1961

A generalization of the expression for the longitudinal dielectric constant of a many-electron system in a periodic potential given by Cohen and Ehrenreich was discussed. The inclusion of local field effects, paying careful attention to the relationship between microscopic and macroscopic quantities, was used in the formulation. The result has the following form for long wavelengths and low frequencies: $\epsilon = \epsilon_c - 4\pi Ne^2/m_a\omega^2$. The second term is the usual acceleration term, N and $m_a$ being appropriate carrier density and an appropriate average effective mass, respectively. This term does not contain a local field correction. The first term, $\epsilon_c$, is the analog of the ordinary atomic polarization and does contain a local field correction which has been calculated explicitly for the weak and tight binding limits. Evaluation of $\epsilon_c$ for more realistic models of crystals was described.

10,982 DOMAIN STRUCTURE OF $NaNO_2$ by S. Nomura, Y. Asao, and S. Sawada (Tokyo Inst. Tech.); J. Phys. Soc. Japan, Vol. 16, pp. 917-923, May 1961

Observations of the 180° domains along the b direction in $NaNO_2$ single crystals are described. The domain boundaries lie parallel to the (100) plane, a fact related to the thermal motion of $NO_2^-$ anions. The domains are ferroelectric. The positive end of a domain etches more rapidly than the negative end, using an alkali etchant; this characteristic is practically reversed when using an acid etchant. Crystals prepared from aqueous solution are almost of single-domain structure, but once heated to near the Curie temperature, the domain structure resembles that of melt-grown crystals.

10,983 PERFECTNESS OF MACRODOMAINS OF $BaTiO_3$ CRYSTALS by K. Aizu and O. Nakada (Hitachi Central Res. Lab.); J. Phys. Soc. Japan, Vol. 16, pp. 923-927, May 1961

The size and density of reversely-polarized microdomains contained within a unidomain c-plate (or a macrodomain of a multidomain c-plate) of $BaTiO_3$ are reported. The evaluation is made under conditions of thermal equilibrium at room temperature, and values both with and without an applied constant electric field are given. Microdomains treated here are confined to those extending to the surfaces of opposite sides of the crystal plate. It is found that plate thickness is inversely proportional to the number of reversely-polarized microdomains, and a plate thicker than about $2 \times 10^{-6}$ cm contains practically no reversely-polarized microdomains. Reversely-polarized microdomains tend to disperse rather than coalesce, and are very difficultly depressed by an electric field. Just below the Curie temperature, it is expected that the critical thickness is considerably larger than the above value, since the domain-wall energy per unit area is fairly small.

10,984 RESEARCH AND DEVELOPMENT OF HIGH TEMPERATURE FERROELECTRIC MATERIALS by E. C. Subbarao, T. Y. Tien and others (Westinghouse Cen. Labs.); U.S. Gov. Res. Rep., Vol. 36, p. 118(A), July 5, 1961 AD 255 979

The effects of small additions of various sintering aids (miner-

alizers) on the properties of $PbTiO_3$ were evaluated. The majority of these additions produced strong $PbTiO_3$ ceramics with densities greater than 90 per cent of theoretical. $CaF_2$ (in concentrations of 0.5 and 1.0 mole per cent), improved the piezoelectric coefficient of $PbTiO_3$ by a factor of 2 to 3. This large increase is believed to be related to the particular microstructure obtained for $CaF_2$ bearing samples. Significant improvements in resistivity could lead to ferroelectric transducers for operation at temperatures beyond those of present commercially available materials.

## CARRIER PROPERTIES

10,985 APPLICATION OF THE SIEMENS METHOD FOR THE MEASUREMENT OF LIFETIME AND RESISTIVITY OF SMALL SLICES OF SILICON by J. Nishizawa (Tohoku U.); Conf. Ultrapurifi. Semicon. Mat., Apr. 11-13, 1961

A relatively rapid, non-contaminating method to measure the resistivity and lifetime of small slices of Si was discussed. The method involves a modification of the Spenke-Kellerman capacity contact method. The modification includes circuit changes and an increase in operating frequency. With this modification, the lifetime of samples as small as 2 x 2 x 5 mm, and the resistivity of samples 5 x 10 x 4 mm were measured.

10,986 RECOMBINATION TIME, MOBILITY, AND TRAP CONCENTRATIONS IN Cu:Cl-DOPED CdSe by S. Triebwasser and G. Cheroff (IBM Res. Ctr.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 110 (A), Mar. 20, 1961

A combination of dynamic relaxation and steady state measurements of photosensitivity made on sintered layers of CdSe over a wide range of Cu doping levels were discussed. Analysis of both photoconductivity decay curves, as well as response to sinusoidal light variation measured as a function of frequency and background light level, yields values of mobility and recombination lifetime as well as trap densities. Over the doping range of 0 to 1000 ppm Cu, the recombination time varies in a highly nonlinear manner from 2 msec to 20 μsec. To first order, the electron mobility is independent of light level (0-500 $\mu w/cm^2$) and doping level with values in the vicinity of 100 $cm^2/vsec$ being observed. Qualitatively, electron trap densities decrease with increased Cu concentration.

10,987 PRODUCTION OF PAIRS IN SEMICONDUCTORS BY LOW-ENERGY ELECTRONS by W. E. Spicer (RCA Labs.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 112 (A), Mar. 20, 1961

Using the velocity distribution of photoelectrons, the probability for pair production in a number of alkali-antimonide semiconductors as a function of electron energy was discussed. Electrons with energies ranging between 0.5 and 6.0 ev have been used. The threshold energy for pair production is found to range from over three times the band gap in $Na_2KSb$ to one or two times the band gap in $Cs_3Sb$. The band gaps of all those materials studied lie between 1.0 and 1.6 ev. Through a detailed analysis of the velocity distribution, it is possible to obtain a measure of the mean free path for pair production as a function of electron energy. This varies from several hundred angstroms for electrons with energies a few tenths of an electron volt above the threshold energy to about 10 A for electrons with energies about one electron volt in excess of the threshold energy.

Recombination in Superconductors - See 11,000

10,988 MEASURING SEMICONDUCTOR LIFETIME by G. K. Wertheim (Bell Labs.); Bell Labs. Rec., Vol. 39, pp. 87-91, Mar. 1961

Various methods for measuring lifetime, particularly the Haynes-Hornbeck method and some of its variations, are discussed. The advantages of high energy pulsed electron excitation are indicated, and applications of this method of excitation are discussed. The mechanism of recombination, the importance of studying lifetime, recombination properties of chemical impurities, and crystal imperfections are also briefly mentioned.

10,989 A MECHANISM FOR THE INTRODUCTION OF RECOMBINATION CENTERS IN GERMANIUM AND SILICON DURING LOW-TEMPERATURE QUENCHING by L. S. Milevskii (Acad. Sci., USSR); Soviet Phys.-Solid State, Vol. 2, pp. 1980-1987, Mar. 1961

An investigation of the effect of quenching from temperatures between 250°C to 600°C on the minority carrier lifetime in Ge and Si is discussed. The results confirm that the recombination centers are formed due to movement of the dislocations away from their impurity "atmosphere." It is also shown that specially created impurity atmospheres at the dislocations may, to some extent, render the dislocation less easily displaced, and thus increase the temperature required to displace the dislocations during quenching, i.e., the commencement of the decrease in lifetime is displaced in the direction of higher temperatures. The process of recombination center annealing must be regarded as a process of resorption of the impurity atmospheres vacated by the dislocations coupled with a process of impurity atmosphere formation at the new dislocation sites.

10,990 MECHANISMS OF SPACE-CHARGE-LIMIT CURRENT IN SOLIDS by G. T. Wright (U. Birmingham); Solid-State Electronics, Vol. 2, p. 165-189, Mar. 1961

The mechanisms of space-charge-limited (SCL) current in solids are discussed. The practical case of a wide band-gap, high-resistivity material containing empty shallow trapping states is studied. One-dimensional and one-carrier (electron) current through a plane parallel crystal is considered for the case when one contact is ohmic and one contact is blocking. At small forward voltage, current occurs by the predominant mechanism of carrier diffusion and increases approximately exponentially with applied voltage. At large forward voltage, current occurs by the predominant mechanism of carrier drift and, after a voltage threshold due to the work-function difference between anode and cathode metals, increases very nearly as the square of applied voltage. Between these two current ranges a smooth transition occurs from a diffusion to a drift mechanism of current and a "virtual cathode" is established in the crystal. Simple analytic expressions describing forward current-voltage characteristics in the exponential and square-law ranges showing that (depending mainly on crystal thickness) high forward conductance or high forward resistance can be achieved are derived.

10,991 HOT AND COLD ELECTRON DIFFUSION by R. Stratton (Texas Instr.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 107 (A), Mar. 20, 1961

The electron current in a semiconductor, at uniform lattice tem-

perature $T_0$, under the influence of a nonuniform high electric field and an electron density gradient, was discussed. The current consists of terms due to conduction, diffusion, and thermal diffusion. The first two terms involve the mobility and diffusion constant, each of which is a function of the electron temperature T; the third is due to the variation of T with position. T itself is not a unique function of the local field but also depends on the local density gradient. Equations for the determination of the first two terms in the spherical harmonic expansion of the distribution function were set up and their solution, under various approximations, was discussed. As an example, computer solutions have been obtained for the volt-current characteristic of a Schottky-barrier metal-semiconductor contact assuming electron scattering due to acoustic phonons only. It turns out that T, in the barrier region, is greater than $T_0$ (i.e., hot electrons) for a bias applied in the reverse direction of the rectifier but less than $T_0$ (i.e., cold electrons) for a bias applied in the forward direction.

Microwave Mobility Changes in Ge - See 10,999

10,992 STUDY OF Li-O INTERACTION IN Si BY ION DRIFT by E. M. Pell (GE Res. Lab.); U.S. Gov. Res. Rep., Vol. 36, p. S-78 (A), July 5, 1961 PB 154 444

The study of Li-O interactions in Si by ion drift in a reverse-biased n-p junction is cited. Effective drift mobilities of $Li^+$ are measured between 20°C and 125°C in Si samples containing oxygen concentrations up to $1.3 \times 10^{18}$ atoms/cc. Under such conditions the $Li^+$ and oxygen will combine to form a complex of the form $LiO^+$. The ratio of the effective drift mobility of free $Li^+$, when measured as a function of temperature, can be used to determine the dissociation constant of $LiO^+$. At high oxygen concentrations the effective drift mobility is found to be inversely proportional to the oxygen concentration, in accordance with the model. The use of this technique for the measurement of oxygen concentrations below $10^{17}$ atoms/cc is discussed, and some examples of such measurements are given.

Hole Scattering in p-Type Ge - See 11,068

10,993 SCATTERING OF ELECTRONS BY ACOUSTIC OSCILLATIONS IN HEXAGONAL CRYSTALS by E. P. Pokatilov (Kishin State U.); Soviet Phys.-Solid State, Vol. 2, pp. 1973-1975, Mar. 1961

The generalized deformation potential method is applied for computing the components of the relaxation-time tensor $\tau$ in the scattering of current carriers by acoustic oscillations in crystals having hexagonal symmetry. An investigation of the interaction of an electron with lattice oscillations necessitates taking into account the tensor nature of the effective mass $m^*$ of the electron, elastic constants of the lattice $\lambda$ and the deformation potential $\underline{a}$. It is shown that hexagonal crystals can have a pronounced elastic anisotropy, which exerts a considerable influence on the components of the tensor $\tau$. A discussion of the relative dependence of the components of $\tau$ on $m^*$, $\underline{a}$, and $\lambda$ is given, using a hexagonal crystal as an example.

## CONDUCTIVITY

Method for Analysis of Conductivity of p-n Junctions - See 11,079

Measurements of Resistivity of Small Si Slices by Modified Spenke-Kellerman Method - See 10,985

10,994 LOW-TEMPERATURE RECOVERY OF RESISTIVITY IN ELECTRON-IRRADIATED GOLD by J. B. Ward and J. W. Kauffman (Northwestern U.); Phys. Rev., Vol. 123, pp. 90-96, July 1, 1961

Two electron irradiations of 99.999 per cent purity, 0.008-in diam gold wire at 13° and 10.5°K, respectively, and subsequent isochronal anneals are discussed. The anneals were carried out in 1- or 2-degree steps from the lowest temperature up to 65°K, and, in addition, the second set of anneals was extended for 1-hr periods at 125°, 170°, 225°, and 260°K. Each of the anneals produced some recovery. The plot of the slope of the isochronal recovery curve showed peaks and indicated a stage I in the annealing, extending up to 45°K, during which 28.5 per cent of the resistivity increment annealed out. From 45° to 65°K (stage II) no distinct processes were observed. Stage II apparently continues up to 240°K; from 45° to 250°K, 36 per cent of the resistivity increment anneals out; 35.5 per cent remained at this temperature. By assigning a suitable frequency factor $K_0$ to each process in stage I, and assuming that the processes are first order (corresponding to recombination of close pairs of vacancies and interstitial), it is possible to calculate the activation energies for each process. For $K_0 = 10^{10}$ to $10^{13}$ $sec^{-1}$, these ranged from 0.037 to 0.045 ev for the first peak to 0.11 to 0.13 ev for the fifth. An explanation is suggested for the major differences between the annealing behavior of gold and copper.

10,995 EFFECT OF HYDROSTATIC PRESSURE ON IONIC CONDUCTIVITY IN DOPED SINGLE CRYSTALS OF SODIUM CHLORIDE, POTASSIUM CHLORIDE, AND RUBIDIUM CHLORIDE by C. B. Pierce (U. Illinois); Phys. Rev., Vol. 123, pp. 744-754, Aug. 1, 1961

Studies of the effect of hydrostatic pressure up to 9000 $kg/cm^2$ on ionic conductivity in NaCl, KCl, and RbCl single crystals doped with divalent impurities over the temperature range 200° to 500°C are discussed. The conductivity in this temperature range is due almost entirely to the motion of extrinsic cation vacancies. The activation volume $\Delta V_m$ for motion of the cation vacancies is $7.7 \pm 0.5$ cc/mole in NaCl doped with $CaCl_2$ and $7.0 \pm 0.5$ cc/mole in KCl doped with $SrCl_2$. The results are in fair agreement with values predicted on the basis of Keyes' empirical expression relating activation volume to activation energy and isothermal compressibility. Sample materials were chosen with the view of testing for a correlation between activation energy and shear modulus. The small shear modulus in KCl and RbCl decreases with increasing pressure, while the reverse is true for NaCl. However, the data are not adequate to draw definite conclusions about such a correlation. The conductivity of RbCl doped with $BaCl_2$ increases by an order of magnitude at the phase transition from the NaCl to the CsCl structure. At 300°C, the transition occurs at 6100 $kg/cm^2$.

10,996 A STUDY OF THE EFFECT OF GAMMA IRRADIATION ON THIN METALLIC FILMS by A. Boornard, J. Steinberg, and D. B. Rosenblatt (Frankford Arsenal); U.S. Gov. Res. Rep., Vol. 36, p. 109 (A), July 5, 1961 AD 255 465

An investigation of radiation effects in thin metallic films prepared by the vacuum evaporation process is reported. Cu and Au films were deposited in vacuum by the thermal evaporation process on soft glass and stainless steel substrates and irradiated at Brookhaven National Lab. at room temperature by Co 60

γ-rays. The electrical resistivity was measured and x-ray diffraction patterns were obtained before and after irradiation of the samples on the glass substrates. Broadening of the x-ray diffraction patterns occurred upon irradiation of the samples on glass, but not on metal substrates. Resistivity changes were observed, but were not correlated with this line broadening.

10,997 CHARACTERISTIC VARIATION OF THE ELECTRICAL CONDUCTIVITY OF RUTILE CERAMICS DURING THE PROCESS OF ELECTRICAL AGING AND REGENERATION by Y. Ya. Kunin and A. N. Tsikin (M. I. Kalinin Polytech.); Soviet Phys.-Solid State, Vol. 3, pp. 158-163, July 1961

An investigation of the variation of the conductivity of rutile ceramics is described. Various hypotheses regarding the mechanism of the ceramics' aging are presented. The experimental data indicates that regeneration in ceramics qualitatively corresponds to a slow change in the conductivity. Current variations caused by switching of the polarity of the applied voltage are discussed. The time dependence of the conductivity, obtained after the electric field intensity was decreased during the ceramics' aging process, is considered.

Effect of Ion Bombardment on the Electrical Properties of W-Ge and W-Si Point Contacts - See 11,072

10,998 INVESTIGATIONS OF INDUCED CONDUCTIVITY IN THIN $Sb_2S_3$ AND $Sb_2Se_3$ LAYERS by V. I. Fomina; Soviet Phys.-Solid State, Vol. 3, pp. 510-512, Sept. 1961

The results of an investigation of electrical conductivity induced by electron bombardment in $Sb_2S_3$ and $Sb_2Se_3$ layers are reported. The dependence of the amplification factor on the electron energy in the exciting beam, current-voltage characteristics of the dark and induced currents, and the dependence of the induced current in the exciting beam were studied. The effect of temperature on all these dependences and on the induced current was also noted.

10,999 MICROWAVE STIMULATED RESISTANCE OSCILLATIONS IN GERMANIUM AT 4°K by H. Kroemer (Varian Assoc.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 116 (A), Mar. 20, 1961

The electrical resistance of several germanium crystals at 4°K was discussed. The resistance was found to oscillate strongly if the crystals were subjected to a microwave field, in addition to being illuminated. The oscillations consist of regularly spaced short pulses (about 3 μsec long) rather than being sinusoidal. The oscillations set in abruptly at a certain microwave power level. They disappear again at higher powers, before ionization breakdown occurs. The pulse repetition frequency is proportional to the illumination level, typical frequencies being in the kilocycle range. The effect was found in both n- and p-type germanium, and for several crystal orientations. It is believed to be due to a change in carrier mobility through microwave heating which in turn produces a change in the microwave coupling. In this way a thermal runaway occurs, leading to relaxation oscillations.

Conductivity of GaAs-AlAs Alloys - See 11,067



11,000 RADIATIVE RECOMBINATION LIFETIME OF ELECTRONS AND HOLES IN SUPERCONDUCTORS by B. N. Taylor, D. N. Langenberg, and E. Burstein (U. Pennsylvania); Bull. Am. Phys. Soc., Ser. II, Vol. 6, pp. 121-122 (A), Mar. 20, 1961

The low-voltage tunneling through oxide barriers between two superconductors was discussed. The tunneling depends on the density of electrons and holes in their conduction and filled bands. The density of carriers can be increased by electrical and optical "injection" processes. The radiative and nonradiative mechanisms which limit the lifetime of the added carriers are (a) the recombination of electrons and holes across the energy gap and (b) the pairing of electrons in the conduction band and the corresponding pairing of holes in the filled band. The electron-hole radiative recombination lifetime, $\tau_{opt}$, was estimated for lead ($E_G = 2.7 \times 10^{-3}$ ev) using the theory of Roosbroeck and Shockley. The frequency dependence of $\eta^2\kappa$ was obtained from the theoretical expressions of Mattis and Bardeen for the complex conductivity. The density of thermally generated carriers was calculated from the B.C.S. theory and from the experimental estimate for the density of states at the Fermi surface in the normal state proposed by Gold. The $\tau_{opt}$ at 2°K is calculated to be 0.4 sec and the recombination radiation spectrum is peaked at $2.9 \times 10^{-3}$ ev.

11,001 MAGNETIC FLUX QUANTIZATION IN A SUPERCONDUCTING RING by J. E. Mercereau and L. L. Vant-Hull (California Inst. Tech.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 121 (A), Mar. 20, 1961

An experimental test on the quantization of magnetic flux trapped by a superconducting ring, as postulated by London, was discussed. This postulate suggests that such trapped flux must occur in integral units of $\phi_0 = (hc/e) \simeq 4 \times 10^{-7}$ gauss cm$^2$. As a consequence the magnetic dipole moment due to such trapped flux must be discrete. This effect has been investigated by looking for a difference in the magnetic moment of a ring when switched between the normal and superconducting states. The moment in the normal state is zero and in the superconducting state proportional to the deviation of the ambient flux from $N\phi_0$. Switching was done thermally at 6 kc and the changing dipole moment detected by the voltage generated in pickup coils loosley coupled to the ring. The experiment was done in a 1-mm indium ring under conditions where the ambient flux $\phi$ was slowly and continuously varied between ± 20 (hc/e). Quantization should exhibit itself as an amplitude modulation of the output signal, the signal going to zero whenever $\phi = N\phi_0$. Experimental results have shown no such quantization effects.

11,002 TUNNELING BETWEEN THE SUPERCONDUCTING PAIRS Pb-Sn AND Sn-In by H. Smith, S. Shapiro, and J. L. Miles (Arthur D. Little); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 121 (A), Mar. 20, 1961

Observation of the tunneling current vs voltage characteristic of superconducting metal-dielectric-superconducting metal sandwiches extended to the cases of Pb-Sn and Sn-In pairs was discussed. A barium stearate film is used as dielectric. A symmetric cusplike current peak and a current jump are observed as predicted at, respectively, the lower voltage and upper voltage limits of the negative resistance region for the Pb-Sn sandwich. Data are presented on the temperature dependence of the energy gap for superconducting tin films. Good agreement is obtained with the predictions of Bardeen, Cooper, and Schrieffer.

11,003 ANALYSIS OF ELECTRON TUNNELING BETWEEN SUPERCONDUCTORS by S. Shapiro and P. F. Strong (Arthur D. Little); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 121 (A), Mar. 20, 1961

The detailed calculations of the tunneling current vs voltage characteristic of a metal-dielectric-superconducting metal sandwich offered by Nicol, Shapiro, and Smith extended to the case where both metals are superconducting were discussed. A negative resistance region in the characteristic and its use as a direct measure of the superconducting energy gap were described. In addition, calculations reveal certain special features that are also in agreement with experiment. These are the existence of a symmetric cusplike peak in the current at the lower voltage limit of the negative resistance region and the existence of a finite current jump at the upper voltage limit. An analytic expression for the magnitude of the current jump in terms of the superconducting energy gaps was obtained. When the values for the energy gaps measured from the negative resistance region are used in this expression, the calculated and measured values of the current jump are in good agreement.

Transition Temperature of La Intermetallic Superconductors - See 11,027

11,004 SUPERCONDUCTING TRANSITION TEMPERATURE OF ISOTOPES OF RUTHENIUM by T. H. Geballe and B. T. Matthias (Bell Labs.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 122 (A), Mar. 20, 1961

Preliminary measurements of the critical temperature $T_c$ of powdered samples of $Ru^{99}$ and $Ru^{104}$ were discussed. The measurements indicate that the dependence of $T_c$ upon mass is much less than the inverse one-half power. While the observed transition is broad, the curves for both isotopes lie considerably closer together than the 0.01° displacement which would be expected if $T_c$ were proportional to $M^{-\frac{1}{2}}$. Further experiments for the purpose of sharpening the transition curves are being performed.

## MAGNETOELECTRIC (GALVANOMAGNETIC) PROPERTIES

11,005 A NOTE ON THE MAGNETORESISTANCE OF PbTe AT HIGH MAGNETIC FIELDS by E. Yamada and K. Shogenji (Hitachi); J. Phys. Soc. Japan, Vol. 16, p. 1475(L), July 1961

The oscillatory behavior of PbTe as a function of H at high magnetic fields is discussed. The period of oscillation is determined by the cyclotron mass which is a function of the relative direction of H with respect to the energy ellipsoid. For several directions of H, the periods are listed and discussed.

11,006 THE CALCULATION OF METALLIC HALL CONSTANTS: TOPOLOGICAL ASPECTS AND APPLICATIONS TO COPPER by J. R. Kauder (Bell Labs.); Bell Sys. Tech. J., Vol. 40, pp. 1349-1367, Sept. 1961

A numerical method, developed to calculate the Hall constant in metals appropriate to high magnetic fields, is discussed. Prediction of the Hall constant depends partly on a repeated computation of a specific topological invariant. Each of several parallel two-dimensional planes in crystal-momentum space must be analyzed to find, on a single sheet of the Fermi surface, the number of nonintersecting closed contours that surround an arbitrary point. This number is related to the effective sign of the charge of the "relevant" electronic carriers in the plane-carriers whose contribution to the Hall constant is based on their orbital area. Applications of this technique have been made to the Pippard model for copper.

11,007 QUANTUM EFFECTS IN CYCLOTRON RESONANCE OF HOLES IN GERMANIUM by J. C. Hensel (Bell Labs.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 115 (A), Mar. 20, 1961

New cyclotron resonance lines observed in germanium using a millimeter-wave Zeeman spectrometer were described. These lines are believed to arise from the quantum effects originating from the degeneracy of the valence band edge as first predicted by Luttinger and Kohn. Measurements were made at 56 kMc/sec and temperatures near 1.3°K. Carriers of both signs were introduced into the sample by white light. Line broadening and other microwave heating effects were avoided by operating the spectrometer at ultra-low power levels ($< 10^{-7}$ w). Under these conditions the electron resonances have $\omega\tau \sim 350$. The samples were high purity p-type Ge slices oriented so the magnetic field could be rotated in the (110) plane. Up to 18 new lines have been observed for a given orientation of the crystal. In addition to the resonances near the heavy hole reported by Fletcher et al., considerable structure has been uncovered near the light-hole and in the intermediate mass regions. The anisotropy of some of the lines was determined.

11,008 SPIN RESONANCES IN REACTOR-IRRADIATED $\alpha$-$Al_2O_3$ by C. G. Young, O. R. Gilliam (U. Connecticut), and P. W. Levy (Brookhaven Natl. Lab.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 117 (A), Mar. 20, 1961

Spin resonances in reactor-irradiated single crystals of $\alpha$-$Al_2O_3$ were discussed. After irradiation for several hours at 100°C, the crystals show an ESR line with $g \approx 2.01$. The linewidth is 26 gauss at 77°K and at 9.2 kMc. This absorption is intense after one week of irradiation; such a dosage also causes 12 or more weaker lines with trigonal symmetry centered about the main line with maximum splitting of about 1600 gauss. All lines anneal out at 500°C. If, subsequent to reactor irradiation, the sample receives $10^6$ – r $Co^{60}$ gamma-ray irradiation at 77°K, a strong 3-line spectrum is obtained characterized by no variation about the c-axis, zero line separation and crossover for 55° orientation, intensity ratio approximately 3:4:3 at 90°, high field line slightly more intense of outermost lines of 0°, $g_\perp > g_{||} > g$ electron, and widths of 22 gauss. This fine structure corresponds to a center with spin $S = 3/2$, more than half-filled shell, and $D = +1.0 \pm 0.1$ kMc. No growth saturation or bleaching by room light were observed; however, this 3-line spectrum disappears with a 1-hr anneal at 200°K.

11,009 MAGNETOPLASMA REFLECTION IN InAs AND GaAs by P. D. Maker, J. Baker, and D. F. Edwards (U. Michigan); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 116 (A), Mar. 20, 1961

Magnetoplasma reflection measurements have been made on n-type samples of InAs and GaAs. On using plane polarized radiation (E⊥H) the single zero-field plasma reflection minimum splits into two minima under applied magnetic fields with separation equal to the cyclotron frequency. The electron effective mass has been estimated from this splitting. Typical values

for InAs are $m^*/m = 0.051$ for an electron concentration of $1.8 \times 10^{18}$ cm$^{-3}$. Small inhomogeneities in carrier concentration can broaden these lines and in some cases completely eliminate one of the reflection minima. Plasma reflection measurements have been used to examine inhomogeneities in samples, and concentration differences as small as 1.0 per cent have been measured. Data for the variation of effective mass with carrier concentration are presented.

## ELECTRICAL PROPERTIES OF SURFACES

11,010 STUDIES OF CLEAVED GERMANIUM SURFACES by S. R. Morrison, D. R. Palmer, and C. E. Dauenbaugh (Honeywell Res. Ctr.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, pp. 106-107 (A), Mar. 20, 1961

Electrical studies of clean (by cleavage) germanium surfaces by the Statz method was discussed. Earlier work has shown that a strongly p-type surface layer is found on clean germanium. The approach concerns the preparation by diffusion of a p-n-p transistor-like structure, and the cleavage of the transistor junctions. Biasing both junctions in the reverse direction, the "channel" resistance across the p-type surface layer is measured. The resistivity upon cleavage was found to be in the order of 100 μmho/sq with an 0.1 v bias on the junctions. The resistivity variations with oxygen admission are similar to earlier work on argon-bombarded and particularly cleaved germanium surfaces.

11,011 OXIDE FORMATION ON CdTe AND ZnTe by H. D. Coghill, R. K. DiCerbo, R. E. Halsted, and M. R. Lorenz (GE Res. Lab.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 212 (A), Apr. 24, 1961

Irreversible changes in the electrical and optical properties of surfaces of single crystals of CdTe and ZnTe on exposure to air were discussed. Electron diffraction measurements indicate these changes are due in part to the formation of $TeO_2$ surface films. The reaction rate increases with increasing temperature. This behavior is consistent with the oxygen-sulfide (e.g., ZnS) reaction in which $SO_2$ is an initial reaction product. Beneath the transparent surface oxide film the oxygen interaction produces a "diffused impurity" layer which also has optical and electrical properties different from the initial sample. One might anticipate n-type conductivity in a layer containing Te vacancies or oxygen substituted for Te. However, p-type conductivity is observed. $TeO_2$ formation does not simply fit into previously proposed mechanisms for the interaction of oxygen with CdTe. Alternative mechanisms remain to be established.

Electrical Properties of Adsorbed Films on Solids - See 10,955

11,012 HYSTERESIS IN THE LARGE-SIGNAL FIELD EFFECT ON SEMICONDUCTOR SURFACES by D. R. Frankl (Genl. Tel. Electronics); J. Electrochem. Soc., Vol. 108, p. 175C (A), Aug. 1961

Hysteresis induced errors in large-signal field effect measurements on semiconductor surfaces are discussed. The finite generation and recombination rates of excess minority carriers can lead to large hysteresis effects even at frequencies $\ll (2\pi\tau)^{-1}$ in large-signal field effect measurements. The hysteresis loop occurs on the inversion-layer side of the conductance vs field curve and widens with increasing frequency and with increasing minority carrier lifetime in the sample. The importance of this effect is that it may lead to appreciable errors in certain point-by-point measuring techniques. Experimental results on Ge and a simple theoretical treatment are presented.

## OTHER ELECTRICAL PROPERTIES

10,013 OSCILLATIONS IN SEMICONDUCTOR PLASMAS by M. Glicksman (RCA Labs.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 116 (A), Mar. 20, 1961

Oscillations observed in semiconductors containing electron-hole plasmas, situated in a magnetic field parallel to the current flow were discussed. It is suggested that these oscillations are part of a class of diffusion instabilities found in gaseous plasmas. A theory applicable to the electron-hole plasma in semiconductors has been derived, and compared with the experiments in germanium and indium antimonide. Calculated values for the threshold longitudinal magnetic fields and the lowest oscillation frequencies are in fair agreement with the observations.

11,014 MULTICOMPONENT MAGNETOPLASMA RESONANCES IN GERMANIUM by B. Rosenblum and R. E. Michel (RCA Labs.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, pp. 115-116 (A), Mar. 20, 1961

Magnetoplasma resonances of the multicomponent plasma consisting of the light and heavy holes in germanium have been observed at 24 kMc. The carrier concentration and therefore the plasma frequency was controlled by varying the temperature of a small ellipsoid of p-type germanium in the 10°K to 15°K region. The preliminary experiments appear to be in qualitative agreement with solutions of the coupled oscillator equations derived by Kittel. In solving these equations the holes were assumed to be two coupled systems with isotropic masses. Electron magnetoplasma resonance in germanium was also observed as a function of the orientation of the magnetic field in the crystal. The line, although broad, appeared to be single. The anisotropy was less than ten per cent when the plasma frequency was two or three times the cyclotron frequency. A careful check of the carrier concentration and the sample shape dependence of the plasma frequency can confirm the expected redundancy of any Lorentz or cavity contribution to the local field acting on the carrier, but the results are interpretable without such corrections. Light modulation is not used in the experiments; the line shapes are therefore simple Lorentzian in contrast to those previously observed.

Tunneling Theory - See 11,074

Tunneling Between Impurity Band-States - See 11,080

Tunneling Between Superconductor Pairs - See 11,000, 11,002, and 11,003

11,015 SIMPLE THEORY OF TUNNELING AND ITS DEPENDENCE ON A MAGNETIC FIELD by P. N. Argyres and B. Lax (Lincoln Lab.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 105 (A), Mar. 20, 1961

A simple theory of tunneling between two parabolic bands, developed by a calculation of the transmission coefficient for an

electron in the WKB approximation, was discussed. The calculation of the tunneling current in a junction of any width is thereby possible. For a very broad junction and a constant electric field the (Zener) tunneling current is identical to that calculated more elaborately by Kane, except for small differences in the numerical coefficients. For an Esaki diode the total tunneling current is found as a function of the applied voltage. The effect of a longitudinal magnetic field on the transmission coefficient is calculated quite simply. It is wholly accounted for by the shift of the band edges and the quantization of the transverse electronic energy due to the magnetic field. Esaki current is found to be reduced by the magnetic field. Small "oscillations" with the magnetic field are also predicted. The effect of a transverse magnetic field is more involved.

## MAGNETIC PROPERTIES

Magnetic Flux Quantization in Superconductors - See 11,001

Relation of Particle Size of Pre-Sintered Powder to Properties of Magnetostrictive Ferrites - See 10,945

Ferrites with High Coercive Force and High Energy Product - See 10,949

11,016 MAGNETIC PROPERTIES OF FERROMAGNETIC METALS AND THEIR ALLOYS ELECTRODEPOSITED FROM SULFAMATE SOLUTIONS by V. Zentner (Hughes Aircraft); J. Electrochem. Soc., Vol. 108, p. 173C(A), Aug. 1961

Investigations of the magnetic properties of nickel, iron, and cobalt electrodeposited from sulfamate solutions and their change with conditions of deposition were discussed. Alloys of nickel-iron, cobalt-iron, and cobalt-nickel plated from sulfamate systems with systematic variations in bath composition were prepared. The dependence of alloy composition on electrodeposition variables was investigated and the relation between magnetic properties, alloy composition, and crystal structure of the deposits was determined.

Method for Reduction of Temperature Coefficient of Initial Permeability of Mn-Zn Ferrites - See 10,946

11,017 MAGNETIC AND COLOR CENTERS IN KCl by E. Sonder (Oak Ridge Natl. Lab.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 114 (A), Mar. 20, 1961

The temperature dependence of the magnetic susceptibility and the absorption spectra of additively colored specimens were measured before and after bleaching and annealing treatments. A 30 per cent decrease in the area of the F band and a larger (33 - 50 per cent) decrease in the density of magnetic centers were caused by bleaching in the F band tail and annealing near 105°C. The fact that the change in magnetic centers exceeds that of the F band indicates not only that most aggregate centers are nonmagnetic but that an F light absorbent nonmagnetic center exists. The results are most easily accounted for by van Doorn and Haven's model of the M center. According to it, the M center is simply a close pair of two F centers, which absorbs both in the M and F bands. Such a two-electron system would not (due to pairing) yield any spin paramagnetism, yet would contribute to the F band absorption.

Ferrites with Square Hysteresis Loops - See 10,950 and 10,951

Ferromagnetic Compounds Having Very Large Coercive Force - See 10,943

11,018 MAGNETIC PROPERTIES OF ELECTROLESS COBALT FILMS AND THEIR APPLICATION IN HIGH DENSITY DIGITAL RECORDING by M. A. Foley (Burroughs); J. Electrochem. Soc., Vol. 108, p. 174C(A), Aug. 1961

Deposition of electroless cobalt on conductive and nonconductive substrates was described and an evaluation of the magnetic properties with respect to thickness, coercive force, and remanence was given. A coercivity range from 40-500 oe can be obtained by varying the plating conditions. The influence of various substrates on the magnetic properties together with bath pH, agitation, and rate of deposition is shown. Crystallographic studies of films of low and high coercivity are included. The dynamic evaluation of thin magnetic films (2-100 μin) in high density recording was discussed.

11,019 REMANENT STATE IN ONE-DIMENSIONAL MICROMAGNETICS by A. Aharoni (Weizmann Inst. Sci., Israel); Phys. Rev., Vol. 123, pp. 732-736, Aug. 1, 1961

A first integral for Brown's nonlinear equations in one dimension is developed. When the external field is zero, another first integral can be found, which enables complete integration of the equations. For a unidirectional anisotropy with an easy direction perpendicular to the plane of the film, one of the integration constants is not determined by the boundary conditions, as if indicating a possibility of continuum of different remanence values for different histories. However, when a small field in the plane of the film is introduced as a perturbation, this degeneracy is removed, and the magnetization can change only in the plane defined by the field and the direction of anisotropy. There are still many discrete possible values for the remanence, each of which determines uniquely the susceptibility at that state.

Gyromagnetic Effect in Ferrites - See 10,947

11,020 MAGNETIC MOMENT OF LANTHANUM MAGNETOPLUMBITE FERRITE by A. Aharoni and M. Schieber (Weizmann Inst.); Phys. Rev., Vol. 123, pp. 807-809, Aug. 1961

Preparation of the composition $La^{3+}Fe^{2+}Fe_{11}^{3+}O_{19}$ by sintering the oxides is described and measurements of its magnetic moment from liquid air temperature to the Curie point are discussed. At the lowest temperature a value of 17.5 Bohr magnetons per formula weight was obtained, as compared with 19 Bohr magnetons of $BaFe_{12}^{3+}O_{19}$. The difference is qualitatively understood if the $Fe^{2+}$ ion is a nearest neighbor to the $La^{3+}$ in the crystal, i.e., in the [12K] site, thus decreasing the total magnetic moment. The Curie temperature is 695°K, compared to 725°K of $BaFe_{12}^{3+}O_{19}$. The lower Curie point can again be qualitatively explained by less exchange interaction with the divalent iron of $LaFe^{2+}Fe_{11}^{3+}O_{19}$, or possibly by the change in unit cell dimension which modifies the short-range exchange interaction between the iron ions.

11,021 ON THE STATICS AND DYNAMICS OF MAGNETIC DOMAIN BOUNDARIES by J. V. Harrington (Res. Lab. of Electronics); U.S. Gov. Res. Rep., Vol. 36, p. S-80 (A), July 5, 1961 PB 154 388

A semiclassical analysis of the variation of spin orientation in 180° and 90° domain walls which takes into account both the

rotational or latitude angle θ and the precessional or longitudinal angle φ of the macroscopic magnetization vector in ferromagnetic single crystals is presented. The Euler equations for the crystal are derived for both θ and φ variations, and solutions of these equations indicate the possibility of a change in spin orientation along a 180° Bloch wall resulting from a precession in φ. This possibility is verified experimentally by some Bitter powder pattern results in which 180° wall breakup is recorded in a single crystal window frame of silicon iron under the action of a moderate vertically applied magnetic field. Further static solutions of the Euler equation for 360° walls or two adjacent 180° walls of similar rotation driven together by an applied field are obtained. When this field is reduced to the order of the coercive force, the equilibrium spacing between 180° walls is about ten wall thicknesses. By including the kinetic energy term characteristic of gyroscopic motion in the Lagrangian and assuming a Rayleigh dissipation function, the Euler equations for wall motion are obtained. The assumption of Rayleigh dissipation leads to a more reasonable variation of wall velocity with losses in the material.

Domain Alignment During Production of Ferromagnetic Ceramic Fibers - See 10,944

Theory of Domain Wall Displacement - See 11,111

Distortion in Antiferromagnetic Lattices Near Their Néel Points - See 10,926

11,022 $Fe^{57}$ MÖSSBAUER EFFECT IN Cu-Ni ALLOYS by G. K. Wertheim and J. H. Wernick (Bell Labs.); Phys. Rev., Vol. 123, pp. 755-757, Aug. 1, 1961

A study of the properties of iron impurity atoms in the complete range of composition of Cu-Ni alloys, by use of the Mössbauer effect of $Fe^{57}$, is discussed. The isomer shift indicates a small decrease in the total electronic density at the $Fe^{57}$ nucleus in going from pure Ni to pure Cu. The magnetic field at the iron nucleus at 0°K decreases by 9 per cent in the range from 0 to 40 per cent Cu. Both results show that only minor changes take place in the atomic configuration of the iron. The linewidth, measured in the paramagnetic alloys, is smallest in pure copper and largest near the middle of the composition range. The rapid change in linewidth with small nickel admixture can result from quadrupole splitting due to the field gradients arising from the spatial charge fluctuations around an impurity atom. Some of the broadening can also arise from an inhomogeneous isomer shift due to a range of surroundings of an iron atom in the alloy.

Paramagnetic Resonance Studies of Irradiated Fluorides - See 10,963 and 10,964

11,023 MAGNETIC PROPERTIES OF $HCrO_2$ AND $DCrO_2$ by R. G. Meisenheimer and J. D. Swalen (Shell Dev.); Phys. Rev., Vol. 123, pp. 831-834, Aug. 1961

Magnetic susceptibility measurements and electron paramagnetic resonance measurements on powdered chromous acid ($HCrO_2$) and deuterated chromous acid ($DCrO_2$) are presented. The Curie constants, derived from the susceptibility results, are consistent with three unpaired electrons associated with each chromium ion. In addition, a large Curie-Weiss θ temperature, indicating a strong exchange interaction, is necessary to account for the results. The most unusual feature of this particular exchange is that it is strongly influenced by deuteration. The electron paramagnetic resonance spectra also show strongly exchange-narrowed lines with a variation between $HCrO_2$ and $DCrO_2$. From a comparison between the calculated and observed linewidths and second moments, a value of the zero-field splitting is estimated. Although no transition has been observed to an antiferromagnetic state, the Curie-Weiss θ temperatures indicate that the ground state is undoubtedly antiferromagnetic for both $HCrO_2$ and $DCrO_2$. Superexchange through the intervening proton or deuteron is probably the main source of any antiferromagnetic exchange coupling. Some of the various mechanisms proposed for superexchange are discussed in relation to chromous acid.

11,024 NUCLEAR SPIN RELAXATION IN SUPERCONDUCTING Al ALLOYS by Y. Masuda (IBM Watson Lab.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 122 (A), Mar. 20, 1961

Measurements of nuclear spin relaxation time $T_{1S}$ in superconducting Al[1-3] measuring $T_{1S}$ as a function of temperature for specimens of Al containing various low concentration of impurities were discussed. The experimental data on Al alloy, which contained 0.055 atomic per cent Zn, agree well with the theory assuming r = 60 and using the same energy gap $2\epsilon_0(0) = 3.25kT_c$ as that used in pure bulk Al(r = 10). Other data on the specimen containing 0.160 at. per cent Ge show that r = 60 and $2\epsilon_0(0) = 3.35kT_c$. If the parameter $\Delta(=\epsilon_0(0)/r)$ represents an anisotropy of the energy gap, the experimental data show that the anisotropy of the energy gap present in the pure Al may be washed out by the impurity scattering, and therefore the energy gap width will be nearly the same as predicted by BCS. Size effect on $T_{1S}$ also was discussed.

11,025 SPIN RESONANCE OF GAMMA-RAY IRRADIATED $\alpha$-$Al_2O_3$ by O. R. Gilliam, C. G. Young (U. Connecticut), and P. W. Levy (Brookhaven Natl. Lab.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 117 (A), Mar. 20, 1961

A paramagnetic resonance absorption at 9.2 kMc in $Co^{60}$ gamma-ray irradiated single crystals of Linde $\alpha$-$Al_2O_3$ was described. This resonance line is about 40 gauss wide at inflection points with $g \approx 2.01$. There is some evidence of a slight shift of g with orientation, but the presence of strong impurity resonances has prevented accurate measurements to date. The growth of this line saturates with less than $5 \times 10^4$r at about $10^{15}$ spins. Most samples were irradiated at 77°K rather than 300°K because of the enhancement in signal. The intensity of the absorption in samples irradiated at 77°K drops about a half after one hour at 200°K. The resonance remains for at least six months at room temperature. Growth saturation, stability and annealing behavior correlate with the behavior of γ-induced optical absorption bands. The resonance is detectable with $5 \times 10^3$r. Irradiation up to $10^7$r causes no increase in intensity over a $5 \times 10^4$r dose.

11,026 PARAMAGNETIC RESONANCE OF F CENTERS IN ALKALI HALIDES by W. C. Holton and H. Blum (U. Illinois); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 112(A), Mar. 20, 1961

The hyperfine coupling of the F electron to nuclei neighboring the negative ion vacancy, measured by electron-nuclear double resonance for F centers in NaCl, LiCl, NaF, and LiF, was discussed. Root second moments of the resonance absorption, obtained from slow passage, agree with values calculated from the hyperfine constants. These experimental results, together with those of previous workers, are compared with the Gourary and Adrian (G and A) theory. The G and A expression, $|\phi(\alpha)|^2 = A_\alpha |\psi(\alpha)|^2$, relates the electron density at the α nucleus to the product of an F-electron envelope function $[\psi(\alpha)]$ with

an amplifying factor ($A_\alpha$). As stated by G and A $A_\alpha$ is shown to be dependent only on the electronic structure of the α ion. The functional dependence of A on the atomic number (Z) is found to be, $A \propto Z^2$.

Paramagnetic Resonance of $\overline{F_2}$ Centers in LiF - See 11,121

Nuclear Magnetic Resonance in GASH - See 11,113

11,027 NUCLEAR MAGNETIC RESONANCE IN INTERMETALLIC COMPOUNDS OF LANTHANUM by R. G. Shulman, B. J. Wyluda, and B. T. Matthias (Bell Labs.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 103(A), Mar. 20, 1961

Nuclear magnetic resonance shifts in superconducting intermetallic compounds was cited. In the solid solution series $(LaRu_2)_x(ThRu_2)_{1-x}$, the superconducting transition temperature is a function of composition with maxima in the vicinity of $x = 0.9$ and 0.15 and a minimum around $x = 0.5$. In these compounds we have measured the $La^{139}$ resonance at constant frequency, which is shifted to higher magnetic fields showing a negative Knight shift. At room temperature the shifts reach maxima at $x = 0.15$ and 1.0 and are smallest around $x = 0.5$, correlating very well with the superconducting transition temperatures. At lower temperatures the shifts increase, e.g., for $x = 1.0$; $(\Delta H/H)|_{300} = 0.54 \times 10^{-2}$ and $(\Delta H/H)|_{77} = 0.94 \times 10^{-2}$. In contrast to $LaRu_2$, negligible shifts of the $La^{139}$ resonance are observed in $LaIr_2$, $LaRh_2$, and $LaOs_2$. Furthermore, in $LaPt_2$ a positive Knight shift of $0.77 \times 10^{-2}$ is measured which is temperature independent to a first approximation. Since, of these compounds, $LaOs_2$ has the highest superconducting transition, i.e., 6.5°K, it was shown that this temperature and the negative Knight shifts are related but not inseparable.

11,028 NUCLEAR RESONANCE IN SUPERCONDUCTING VANADIUM by R. J. Noer and W. D. Knight (U. California); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 122(A), Mar. 20, 1961

The resonance of $V^{51}$ in the superconducting metal down to a temperature of 1.5°K, and compared with the normal resonance above 4°K ($T_c = 5.1$°K) was described. The sample consists of 0.2 g of vanadium in a 1 x 1 x 3 cm stack of flat 900-A films which were evaporated onto 0.00025-in Mylar sheets. The critical field was 2500 gauss at 4.2°K and > 10,000 gauss at 3°K. The linewidth was 14 kc at all temperatures, and the intensity varied only according to the Boltzmann factor. The resonance frequency was observed to be the same in the normal and superconducting states, inferring that electron spin paramagnetism is not reduced in the superconductor by more than 10 per cent, which is the experimental accuracy.

11,029 PARAMAGNETIC RESONANCE OF $Cr^{3+}$ IN GASH by G. Makhov and O. Risgin (U. Michigan); Bull. Am. Phys. Soc., Ser. II, Vol. 6, pp. 117-118(A), Mar. 20, 1961

X-band paramagnetic resonance of $Cr^{+++}$ in GASH (guanadine aluminum sulfate hexahydrate) at three temperatures, 300°, 77° and 4.2°K was discussed. The observed spectra can be accounted for by a simple axial field model with the axial field component D increasing with decreasing temperature. At 4.2°K superhyperfine structure was observed in the $\frac{1}{2} \rightarrow -\frac{1}{2}$ transition, and was ascribed to contact interaction between the nuclear magnetic moments of protons in the waters coordinated to the $Cr^{3+}$ and the $Cr^{3+}$ electronic moment. No effect of ferroelectric domains was observed. The crystal lends itself well to stimulated emission and to ENDOR experiments.

11,030 PARAMAGNETIC RESONANCE OF $Cu^{3+}$ IN $Al_2O_3$ by S. Geschwind and J. P. Remeika (Bell Labs.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 116(A), Mar. 20, 1961

The paramagnetic resonance of $Cu^{3+}$ (configuration $3d^8$ which is isoelectronic with $Ni^{2+}$) was observed. The $Cu^{3+}$ entered substitutionally for the Al in the $Al_2O_3$ lattice. An axial spectrum with $S = 1$ is observed with a hfs pattern of four lines for each of the two fine structure components corresponding to the Cu nuclear spin of $I = 3/2$. While the hfs components of the $Cu^{63}$ could not be resolved from those of the $Cu^{65}$, a broadening of the outer hyperfine components is observed in good agreemer with the known Cu nuclear magnetic moment ratios. The result at low temperature are fitted at 24 kMc with the following parameters: $D = -0.18838 \pm 4\ cm^{-1}$, $g_{\parallel} = 2.0784 \pm 5$, $g_{\perp} = 2.0772 \pm 5$, $A(Cu^{63}) = -64.6 \pm 0.6 \times 10^{-4}\ cm^{-1}$, $B(Cu^{63}) = -60.2 \pm 0.6 \times 10^{-4}\ cm^{-1}$. The sign of D was found by observing the relative intensity of the fine structure components at low temperature. The sign of A was found from the second-order shifts in the hfs intervals. These results for $Cu^{3+}$ are compared with those for $Ni^{2+}$ in the same lattice in terms of the excited states of these ions.

11,031 ELECTRON-NUCLEAR INTERACTIONS OF $Cu^{3+}$ IN SAPPHIRE by J. Eisinger, W. E. Blumberg, and S. Geschwind (Bell Labs.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 117(A), Mar. 20, 1961

The $Cu^{3+}$ ion in sapphire was studied in considerable detail by use of the electron nuclear resonance (ENDOR) technique. All transitions of the type $\Delta M_S = 0$, $\Delta m_I = \pm 1$ for the levels $M_S = \pm 1$ were observed for $Cu^{63}$ and $Cu^{65}$ with linewidths of about 50 kc with $H_0 = 6300$ oe parallel to the c axis and T = 1.3°K. The observed ENDOR spectrum could be fitted satisfactorily only by postulating an effective field at the nucleus equal to $(1 + \delta)H_0$, where $\delta = 0.0135 \pm 0.0022$. δ reflects the field-dependent term which arises in second order from the $I \cdot L$ and $H \cdot L$ interactions. Positive δ's of this order of magnitude are to be expected for all transition metals. The interaction constants with their probable errors are $A_{63} = -192.982 \pm 0.007$ Mc, $A_{65} = -206.715 \pm 0.008$ Mc, $B_{63} = -179.6 \pm 1.2$ Mc, $B_{65} = -192.4 \pm 1.3$ Mc, $e^2qQ_{63} = -0.058 \pm 0.004$ Mc, where A and B refer to the parallel and perpendicular hyperfine interactions, respectively. From the above the hyperfine anomaly $\Delta = (A_{63}/A_{65}) \times (g_{65}/g_{63}) - 1 = (0.015 \pm 0.005)$ per cent. Since Δ for an $s_{\frac{1}{2}}$ electron is $(0.015 \pm 0.002)$ per cent for Cu one can conclude that $s_{\frac{1}{2}}$ electrons polarized by s-d interactions are largely responsible for the observed A (< 0).

11,032 HYPERFINE STRUCTURE OF $Fe^{57}$ IN MgO by E. S. Rosenvasser (Columbia U.) and G. Feher (Bell Labs.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 117(A), Mar. 20, 1961

The hyperfine structure of $Fe^{57}$ in single crystals of MgO containing $Fe^{3+}$ as an impurity was resolved completely at 1.3°K and ~ 9000 Mc. The paramagnetic resonance spectrum showed two satellites, one on either side of the main $(\frac{1}{2} \leftrightarrow \frac{1}{2})$ transition, with integrated intensities corresponding to the natural abundance of $Fe^{57}$. The total separation of the satellite lines was found to be $10.8 \pm 0.2$ φ corresponding to an internal field at the $Fe^{3+}$ nucleus of $2.2 \times 10^5$ φ. This value is, within a few per cent, the same as for the isoelectronic $Mn^{++}$ impurity in MgO. The origin of this hyperfine field has been shown by several authors to be due to the polarization of the core s electrons by the 3d electrons.

## MAGNETIC PROPERTIES (Cont'd)

11,033 PARAMAGNETIC RESONANCE OF ZnTe:Mn by G. H. Azarbayejani, C. Kikuchi, and D. Mason (U. Michigan); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 117(A), Mar. 20, 1961

Spin resonance measurements of ZnTe containing about 0.01 per cent $Mn^{2+}$ were carried out to augment the information on $Mn^{2+}$ ions in the cubic $A_{II}B_{VI}$ compounds, ZnS and CdTe, reported earlier. The g value at 77°K is about 2.005. The cubic field parameter 3a is about 0.00348 $cm^{-1}$ at 4.2°K. This is to be compared with 0.00233 $cm^{-1}$ and 0.0084 $cm^{-1}$ for ZnS and CdTe, respectively. Measurements indicate that the hfs coupling constant A is temperature dependent, having the values 62.2, 61.0, and 60.5 gauss at 300°, 77°, and 4.2°K, respectively. This temperature dependence is in contrast to that of CdTe, for which preliminary measurements give 60.6, 61.7, and 61.6 gauss at 300°, 77°, and 4.2°K, respectively.

## OPTICAL PROPERTIES

Noise Equivalent Power in Thin Film Infrared Detectors - See 11,104

11,034 OPTICAL CONSTANTS AND REFLECTANCE AND TRANSMITTANCE OF EVAPORATED ALUMINUM IN THE VISIBLE AND ULTRAVIOLET by G. Hass and J. E. Waylonis (USASRDL); J. Opt. Soc. Am., Vol. 51, pp. 719-722, July 1961

Measurements of the optical constants and of the reflectance and transmittance of evaporated aluminum films produced from the purest grade of aluminum with extremely fast evaporation of about $10^{-5}$ mm Hg are presented. The optical constants determined by Drude's polarimetric method from opaque films and by reflectance, transmittance, and true thickness measurements of semitransparent films are given. For extremely fast evaporated films the optical constants were found to remain unchanged down to film thicknesses of less than 100 A. Data are given on the reflectance and transmittance of semitransparent aluminum films on glass and fused quartz as a function of wavelength from 220 mμ to 650 mμ.

11,035 ELECTRICAL, OPTICAL, AND ELASTIC PROPERTIES OF CRYSTALS OF THE DIAMOND TYPE. Part III. DISPERSION AND ABSORPTION OF LIGHT by V. S. Mashkevich (Kiev Polytech. Inst.); Soviet Phys.-JETP, Vol. 9, pp. 76-80, July 1959

A theory for the dispersion, double refraction, and single-phonon absorption of light due to lattice vibrations in diamond type crystals in the infrared region is developed. The parameters of the theory are determined and the effects of lattice vibrations are quantitatively investigated.

Transmissivity of Ge Films - See 11,057

11,036 DIFFUSE REFLECTANCE OF POWDERS by N. T. Melamed (Westinghouse Res. Labs.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 112(A), Mar. 20, 1961

An equation which relates the reflectance of powders to the optical absorption coefficients of the bulk materials, their indexes of refraction and their particle size was derived. Use of the equation permits the determination of absolute optical absorption coefficients with good accuracy on materials which are not readily available in a form suitable for direct transmission measurements. In addition, the equations permit the calculation of a number of properties of luminescent powders, e.g., quantum yields in the presence of self-absorption.

Effect of Temperature on Absorption Spectra of Additively Colored KCl - See 11,017

11,037 OPTICAL ABSORPTION SPECTRA OF IMPURITY IONS OF THE FIRST TRANSITION SERIES IN ZnS by R. E. Dietz and R. Pappalardo (Bell Labs.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 110(A), Mar. 20, 1961

The optical absorption spectra of single crystals of ZnS doped by diffusion with ions of the first transition series were studied in the region of 4 to 0.3 μ at room temperature, 78° and 4.2°K. By comparing the observed spectra with that predicted by the crystal field theory, the ionic charge and site symmetry of Cu, Ni, Co, Fe, Mn, and Cr impurities were found to be consistent with the respective divalent ion in tetrahedral coordination. Vanadium is probably present in the trivalent state, while the spectrum of Ti is not well understood. In some samples containing Cu, absorptions other than those associated with the divalent ions are observed, suggesting the presence of more than one valence state. The empirical values of the parameters Dq, B, and C for the various ions in ZnS are in good agreement with those observed for CdS. The absorption spectra of Cu, Mn, and V agree very well with the fluorescence excitation spectra reported by other workers for phosphor powders of ZnS, both with respect to energies and relative intensities of the various bands. However, the emissions reported for these phosphors do not appear to correspond to crystal field transitions within the impurity ion.

11,038 ULTRAVIOLET ABSORPTION BANDS OF KI DISSOLVED IN KCl by H. Mahr (Cornell U.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 114(A), Mar. 20, 1961

Absorption bands due to small admixtures of KI in KCl were observed in single crystals. At room temperature only one absorption band due to KI is detectable. Position and half-width of this band are 6.6 and 0.3 ev, respectively. The height of the absorption maximum is proportional to the KI concentration in the melt, ranging from $10^{-5}$ to $5 \times 10^{-3}$ mole fraction KI. At liquid-nitrogen temperature a second band appears right at the edge of the fundamental absorption of KCl. The results will be discussed and compared with measurements of pure KI. The oscillator strengths of the bands were determined by use of Smakula's formula.

11,039 LATTICE ANHARMONICITY AND OPTICAL ABSORPTION IN POLAR CRYSTALS. Part II. CLASSICAL TREATMENT IN THE LINEAR APPROXIMATION by A. A. Maradudin (Westinghouse Res. Labs.) and R. F. Wallis (U.S. Naval Res. Lab.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, pp. 119-120(A), Mar. 20, 1961

An expression for the elements of the dielectric susceptibility tensor for an ionic crystal was discussed. The expression was derived in a manner analogous to that employed by Kubo in his treatment of magnetic susceptibility. In the high-temperature (classical) limit, this expression reduces to the Laplace transform of the autocorrelation function of the single normal coordinate which interacts directly with the external radiation field. This formalism was applied to the calculation of the

high-temperature linear optical absorption coefficient of an anharmonic ionic crystal for which we have retained only cubic anharmonic terms in the lattice Hamiltonian. The Laplace transform of the autocorrelation function to lowest order in the anharmonic coupling constant was found by solving the equations of motion for the normal coordinates after they have been linearized. The linear absorption coefficient obtained from the susceptibility tensor is of Lorentzian form with a frequency-dependent damping constant which varies linearly with temperature. The absorption coefficient for a diatomic linear chain with nearest-neighbor interactions has been evaluated.

11,040 LATTICE ANHARMONICITY AND OPTICAL ABSORPTION IN POLAR CRYSTALS. Part III. QUANTUM THEORY by R. F. Wallis (U.S. Naval Res. Lab.) and A. A. Maradudin (Westinghouse Res. Labs.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 120(A), Mar. 20, 1961

A quantum mechanical theory for optical absorption associated with the lattice vibration of an ionic crystal was discussed. Cubic anharmonic terms in the potential energy are included. A generalized Weisskopf-Wigner time-dependent perturbation method has been employed to solve the quantum mechanical equations of motion in the limit of long times. The present treatment retains certain intermediate states which are omitted in a related treatment of Bom and Huang. Qualitative information concerning the frequency dependence of the optical absorption is obtained by applying the general results to a simplified model of an ionic crystal. The temperature dependence of the absorption is investigated in the high-temperature limit.

11,041 LUMINESCENCE IN SOLIDS by R. B. Murray (Oak Ridge Natl. Lab.); J. Opt. Soc. Am., Vol. 51, pp. 808-811, July 1961

A series of papers on the luminescence of solids is reviewed. On the luminescence of alkali halides, articles on heavy metal activated solids are cited. Further papers on luminescence in molecular solids, electroluminescence, some theoretical interpretations, and, finally, application to scintillators are presented. This review covers the period January 1959 through September 1960 for the journal Optics and Spectroscopy.

11,042 LUMINESCENCE OF IMPURITY CENTERS. Part III. by A. M. Ratner and G. E. Zil'berman; Soviet Phys.-Solid State, Vol. 3, pp. 499-506, Sept. 1961

Calculations of the form of the absorption and luminescence bands on the basis of a quantum mechanical examination of the ion motion, taking into account variations of the elastic lattice constants during electron transition, are presented. The relationship between the elastic constants of a lattice distorted by the introduction of an impurity atom and the parameters defining the form of the absorption and luminescence in the classical case is established. It is shown that in the tight bond case the classical theory contains only a small number of parameters defining the interaction between the impurity atom and its nearest neighbors. At temperatures above one fifth the Debye temperature of the crystal the results, as in the classical case, are expressed by the elastic constants of this interaction. At lower temperatures, the dispersion law for normal ideal lattice vibrations also enters into the expression of the form of the adsorption and luminescence spectra.

11,043 LUMINESCENCE OF IMPURITY CENTERS. Part IV. by A. M. Ratner; Soviet Phys.-Solid State, Vol. 3, pp. 513-519, Sept. 1961

Certain special cases of Ratner and Zil'berman's theory concerning the form of the absorption and luminescence bands are examined. One case is that of a crystal with a rocksalt type of structure where the parameters of the theory in the explicit form are expressed in terms of the elastic constants of the lattice. The thermal transition probability is calculated taking into account the variation of the elastic lattice constants during electron transition. The ion motion is subjected to quantum mechanical treatment. As in the classical case, the deviation from the law of mirror symmetry (related to the variation of the elastic constants) exerts an important effect on the thermal transition probability.

11,044 FLASHLIKE RISE OF LUMINESCENCE. Part III. EFFECT OF THE INTENSITY OF THE EXCITING AND DE-EXCITING LIGHT by N. A. Tolstoi, A. M. Tkachuk, and A. I. Ryskin (Acad. Sci., USSR); Optics and Spectrosc., Vol. 10, pp. 110-112, Feb. 1961

The magnitude and area of the flash in the long wavelength luminescence band, shown to be independent of the intensity of the exciting light owing to identical population of the first trapping levels, is discussed. Data are presented to show that the form of the rising portion of the short-wavelength luminescence band is affected only by the number of electrons or holes involved in the first trapping.

11,045 AN ANALYSIS OF ELECTROLUMINESCENT BRIGHTNESS WAVES by W. T. Eriksen and H. Ahlburg (Raytheon); Solid State Electronics, Vol. 3, pp. 11-17, July 1961

Using the concept of impact ionization and certain assumptions concerning phase relationships between the applied voltage and exciting electrons an equation giving the time dependence of the instantaneous brightness of electroluminescence is derived. Solutions of this equation are compared to experimental brightness waves and similarities pointed out. The existence of secondary peaks in the brightness wave are predicted without reference to trapping phenomena or delayed recombination.

11,046 LUMINESCENCE OF MIXED ALKALI HALIDE CRYSTALS by D. Dutton and K. Teegarden (U. Rochester); U.S. Gov. Res. Rep., Vol. 35, p. 628(A), May 16, 1961
PB 153 670

The excitation and emission spectra of a KCl crystal containing about 0.01 per cent KI are evaluated. No luminescence occurs at room temperature. At 80°K excitation bands occur at 6.73 and 7.18 ev; these correspond to the iodide ion absorption bands. The 7.18 ev absorption band appears on the "tail" of the KCl absorption edge, but is quite distinct in the excitation spectrum. An additional excitation band is observed at 7.6 ev. This is well within the strong-absorption region of KCl. Excitation in any of these bands gives rise to a broad emission band peaking at 3.06 ev. In nominally pure KCl, at 80°K there is an excitation band at 7.6 ev. The observations have been repeated on additional samples of KCl and KCl:I with the same qualitative results. A method for measuring the concentration of $I^-$ in KCl:I crystals has been developed.

11,047 FLUORESCENCE AND OPTICAL MASER EFFECTS IN $CaF_2:Sm^{++}$ by W. Kaiser, C. G. B. Garrett, and D. L. Wood (Bell Labs.); Phys. Rev., Vol. 123, pp. 766-776, Aug. 1961

Measurements of absorption, emission, activation spectra, and

fluorescence lifetime in $CaF_2$:$Sm^{++}$ are reported. A revised level scheme is proposed. Observations of optical maser effects were made at liquid hydrogen and liquid helium temperatures over a wide range of pumping intensities. For illumination in the 6400-A band, the threshold intensity of illumination was about 20 w $cm^{-2}$. The dependence of the intensity of the maser beam on the pumping intensity is cited. Photographic observations show that on one particular sample five distinct frequencies were present in the maser signal, and that the number of modes excited was of the order of 1000.

11,048 EDGE EMISSION IN ZnSe CRYSTALS AT LOW TEMPERATURES by O. W. Larson, L. S. Pedrotti (Air Force Inst. Tech.), and D. C. Reynolds (Aeronautical Res. Lab.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 111(A), Mar. 20, 1961

Fluorescence near the fundamental absorption edge in ZnSe single crystals was investigated at 77° and 4.2°K. The ZnSe crystals, about 0.2 mm thick, were grown from the vapor phase. At both 4.2 and 77°K the crystals were irradiated with ultraviolet light and the fluorescence was photographed with the Bausch and Lomb two-meter grating spectrograph. The structure of the emission at 4.2°K contains a series of lines and three broad bands. The lines, located just to the long wavelength side of the absorption edge, have wavelengths of 4420, 4449, 4497, 4550, 4602, and 4653 A. The last five lines have a separation energy approximately equal to the measured value of the phonon energy, 0.027 ev. The three broad bands, varying in width from 500 to 1000 A are centered near 4950, 5350, and 6110 A. At 77°K the intensity of the fluorescence is reduced and the structure is changed. Two lines, less intense, are found near the absorption edge, one at 4421 A and one at 4435 A. The three broad bands are less intense and somewhat more diffused.

11,049 CdS IN THE NEAR INFRARED UNDER ELECTRON BOMBARDMENT by B. A. Kulp (Aeronautical Res. Lab.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, pp. 110-111(A), Mar. 20, 1961

Fluorescence bands at 8600 and 10,500 A in platelet type single crystals of CdS of the order of 100 μ in thickness were observed when the crystals are bombarded with 300 kev electrons at room temperature. The intensity of the 10,500 A band is almost independent of electron beam current in the range 0.5 to 5 $\mu a/cm^2$. The intensity of the 8600 A band varies approximately linearly with the intensity of the electron beam in the same current range. Both bands decrease in intensity by a factor of about 5 (in several crystals) when the temperature is lowered to -195°C. The 8600 A band is removed from these platelets by bombardment at 300 kev at a level of 5 $\mu a/cm^2$ for a period of 10 to 50 hr depending on the initial intensity of the fluorescence. The crystal resistivity increases as the fluorescence is removed. However, when the fluorescence is no longer detectable no further change in resistivity is observed. The total change in resistivity before and after removal of the fluorescence is dependent upon the initial intensity of the fluorescence band.

11,050 EXCITATION ENERGY TRANSFER IN RIGID SOLUTIONS OF ORGANIC SUBSTANCES by I. M. Rozman (Acad. Sci., USSR); Optics and Spectrosc., Vol. 10, pp. 178-182, Mar. 1961

Measurement of the efficiency of the transfer of electronic excitation energy from p-terphenyl to 1, 3, 5-triphenyl-$\Delta^2$-pyrazoline in polystyrene, and the fluorescence yield of p-terphenyl as a function of the concentration of the energy acceptor is reported. For an acceptor concentration ~0.01 mole/liter, transfer by means of resonance interaction of the molecules plays the principal role. It is proposed that the deviation from the Foerster-Galanin theory is associated with the migration of energy via the solvent.

11,051 DECAY OF PHOSPHORESCENCE FROM A DISTRIBUTION OF TRAPPING LEVELS by W. L. Medlin (Socony); Phys. Rev., Vol. 123, pp. 502-509, July 15, 1961

The behavior of the parameters "b" and "m" of the phosphorescence decay relation $I = I_0 (b/b + t)^m$ are reassessed for temperatures near the glow peak; results based on the assumption that the emptying of traps is the rate determining step in the decay process are discussed. Previously observed discrepancies are thus accounted for by assuming a first-order decay from a distribution of trapping levels. Gaussian distributions are assumed for most of the results but it is shown that other distributions produce similar results. The first-order mechanism is justified by considering the relative magnitude of the rate constants for trap emptying, retrapping, and recombination. At temperatures well above the glow peak this assumption no longer is justified but in this range the second-order decay predicts the observed results for b and m. The effects of retrapping and of crystal dimensions are considered. Also the effect on the glow peak of having a distribution of levels rather than a set of discrete levels is worked out and it is shown that the peak is broadened appreciably even for relatively narrow distributions.

11,052 POLARIZATION OF PHOSPHORESCENCE IN ORGANOPHOSPHORS by V. A. Pilipovich (Acad. Sci., USSR); Optics and Spectrosc., Vol. 10, pp. 104-107, Feb. 1961

The anisotropy of the afterglow and total luminescence of organophosphors is studied. A variation in the degree of polarization of β-phosphorescence in the emission spectrum was found for all the compounds investigated. The results are discussed from the viewpoint of the hypothesis of the complex structure of a metastable state.

11,053 FINAL STAGES OF LUMINESCENCE DECAY IN PHOSPHORS WITH LEVELS OF SEVERAL KINDS by V. V. Antonov-Romanovskii (Acad. Sci., USSR); Optics and Spectrosc., Vol. 10, pp. 92-95, Feb. 1961

A calculation of luminescence decay, carried out for the later stages of decay when only the deepest traps of either sign are effective, is discussed. The probability of repeated capture is assumed to far exceed the probability of recombination.

11,054 THE LUMINESCENCE PROPERTIES OF GOLD-ACTIVATED ZINC SELENIDE by L. Ya. Markovskii and R. I. Smirnova (Acad. Sci., USSR); Optics and Spectrosc., Vol. 10, pp. 98-99, Feb. 1961

Certain luminescence properties of gold-activated zinc selenide under photoexcitation and cathodoexcitation are described. The phosphor has an emission near 700 mμ and has a relatively low inertia and a highly stable spectral composition at elevated temperatures.

11,055 ORIGIN OF ANOMALOUS PHOTOVOLTAIC EFFECT IN ZnS AND CdTe by A. R. Hutson (Bell Labs.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 110(A), Mar. 20, 1961

Anomalously high-photovoltaic effects observed on stack-faulted

crystals of ZnS and evaporated polycrystalline films of CdTe were discussed. Previous attempts to explain these effects have postulated p-n junctions or barriers but have given no satisfactory explanation of their origin or the fact that their individual photovoltages must add in series. The present model proposes that the barriers are produced piezoelectrically by strain gradients occurring at the stack faults and grain boundaries. The strain in ZnS is postulated to arise from a slight difference between the cubic and hexagonal lattice constants perpendicular to the c axis. Hence the barrier fields are produced in one direction in the cubic material and the opposite direction in the hexagonal material. Selective absorption of light can then determine photovoltage sign. The strain in the CdTe films probably arises from differential expansion with respect to the substrate and is localized in necks between grains in which the fields will have the same direction to within the degree of crystal orientation of the film.

11,056 TEMPERATURE DEPENDENCE OF ANOMALOUS PHOTOVOLTAGES IN ZnS by G. Cheroff (IBM Res. Ctr.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 110(A), Mar. 20, 1961

Measurements of the wavelength dependences of the open circuit photovoltages and short circuit photocurrents at various temperatures in the range between 77° and 580°K were discussed. The open circuit voltage increased in general below room temperature, but in some samples was found to reach a minimum at about 430°K and then became larger with increasing temperature. The short circuit photocurrents uniformly increased with increasing temperature. The data indicate that a simple p-n junction mechanism is not valid.

11,057 OPTICAL CONSTANTS OF GERMANIUM IN THE REGION 0-27 EV by O. P. Rustgi, J. S. Nodvik, and G. L. Weissler (U. Southern California); U.S. Gov. Res. Rep., Vol. 36, p. 109(A), July 5, 1961 AD 255 431

The reflectivity has been measured for Ge crystals over the energy range 7.6 - 18.0 ev and the transmissivity for an evaporated Ge film over the range 16.6 - 27.4 ev. The reflectivity data near normal incidence, combined with existing data at lower energies were used in the Kramers-Kronig dispersion relation to evaluate the index of refraction and extinction coefficient of Ge over the range 0 - 18 ev. Electron characteristic losses are predicted at 10 and 15 ev, consistent with those observed at 11 and 16 ev. The plasma frequency of bulk Ge as determined by the optical data is 10 ev.

11,058 REFLECTION OF NOBLE GAS IONS AT SOLID SURFACES by H. D. Hagstrum (Bell Labs.); Phys. Rev., Vol. 123, pp. 758-765, Aug. 1, 1961

A method for distinguishing the reflection of ions at solid surfaces as ions or as metastable atoms is described. Results are given for $He^+$, $Ne^+$, and $Ar^+$ ions incident on clean W, Mo, and Si (100) and on contaminated W, Hf, and Ge (111) surfaces. The reflection coefficient of ions to ions ($R_{ii}$) is found to be small (0.0004 to 0.002) and essentially independent of incident ion energy. The reflection coefficient of ions to metastable atoms ($R_{im}$) is found to increase with ion energy from values comparable to $R_{ii}$ at 10 ev to values as high as 0.04 at 1000 ev. Discussion of these results is given in terms of the known resonance and Auger transitions which can occur near a solid surface for ions of sufficiently large ionization energy. The results can be accounted for only if ions are transformed to metastable atoms very close to the surface, and a possible mechanism for this process is proposed.

## THERMAL PROPERTIES

Specific Heat and Thermal Expansion of fcc Crystals - See 10,975

11,059 LOW-TEMPERATURE SPECIFIC HEAT OF INDIUM AND TIN by C. A. Bryant and P. H. Keesom (Purdue U.); Phys. Rev., Vol. 123, pp. 491-499, July 15, 1961

A study of the heat capacities of indium and tin measured between 0.4 and 4.2°K is presented. In the normal state, the specific heat could be represented by $At^{-2} + \gamma T + \alpha T^3 + \beta T^5 + \mu T^7$. For Sn, in molar millijoule units, A = 0; $\gamma$, the coefficient in the electronic term, is 1.80; $\alpha = 0.242$, corresponding to a Debye temperature, $\theta_0$, of 200°K; $\beta = 0.004$; and $\mu = 0.00014$. For In, A, the coefficient of a nuclear electric quadrupole term, is calculated to be $8.97 \times 10^{-4}$ from resonance data; $\gamma = 1.61$ for one ingot and 1.59 for another; $\theta_0 = 109°$ and 108°K; and $\beta = 0.008$. In the superconducting state, the specific heat of Sn could be expressed as the normal lattice term plus an electronic term of the form $a\gamma T_c \exp(-bT_c/T)$, with $T_c = 3.70$°K (0.02 degree lower than found in a magnetic measurement), $a = 7.63$, and $b = 1.41$ when $2 < T_c/T < 7$; the value of b agrees with infrared measurements of the energy gap. This sort of analysis could not be applied to In, for below 0.8°K the total superconducting specific heat was less than the normal lattice term. A possible interpretation is that $\theta_0$ is 99 per cent higher in the superconducting state than in the normal metal at 0.4°K; this is not supported, however, by the recent acoustic measurements of the elastic constants by Chandrasekhar and Rayne. The anomaly is not yet understood, but a few plausible explanations are discussed.

11,060 ANHARMONIC CONTRIBUTIONS TO SPECIFIC HEAT by J. M. Keller and D. C. Wallace (Iowa State U. and Ames Lab., U.S. AEC); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 119(A), Mar. 20, 1961

Appreciably above the Debye temperature, the lattice specific heat (at constant volume) of a solid due to a harmonic lattice potential is independent of temperature. Including anharmonic parts of the lattice potential makes a contribution to specific heat nearly linear in temperature. Terms in the potential cubic and quartic in lattice displacements contribute, respectively, positively and negatively to specific heat, and the net sign is not clear. Calculations on crystals with a single atom per unit cell, neglecting dependence of phonon frequency on polarization and on direction of propagation, show that the net effect is one of specific heat decreasing as temperature increases. The calculations are based on central Lennard-Jones forces in bcc and fcc crystals. Nearest and next-nearest neighbor forces and phonon dispersion were considered.

11,061 MAGNETIC FIELD DEPENDENCE OF THE THERMAL CONDUCTIVITY OF SUPERCONDUCTING TIN FILMS by D. E. Morris and M. Tinkham (U. California); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 122(A), Mar. 20, 1961

The change in the thermal conductivity of superconducting tin films which is produced by application of a magnetic field parallel to the plane of the films was discussed. The thermal conductivity appears to increase as $H^2$ up to the vicinity of the

critical field. It then changes to a field-independent value characteristic of the normal state at all higher fields. For a 2500 A film, the quadratic change typically reaches 25 per cent of the total change. The observed effect is insensitive to small tilts of the applied field out of the plane of the film. At temperatures of 1.2°, 1.7°, and 2.1°K, the effect is similar except for the usual dependence of $H_c$ on temperature. The absolute magnitude of the quadratic effect is roughly the same for films between 700 and 2400 A thick, while application of the critical field produces a greater change for thicker films. This is consistent with the assumption that only the surface penetration region is affected by a subcritical field. Orientations of the induced persistent currents perpendicular and parallel to the direction of heat flow give similar results.

11,062 CRYOGENIC THERMOELECTRIC COOLING by J. E. McCormick (Griffiss AFB); U.S. Gov. Res. Rep., Vol. 36, p. 106(A), Sept. 20, 1961 AD 259 770

The thermodynamics of thermoelectric cooling are discussed. A hypothetical thermoelectric device exhausting heat to a liquid nitrogen bath is described and the limitations of such a device are considered. Phenomena that may improve the performance of thermoelectric materials in the low temperature range are examined.

Measurement of the Thermoelectric Power of Refractory Oxides - See 10,980

11,063 THERMOELECTRIC POWER OF SILVER HALIDES by R. W. Christy (Dartmouth Coll.); U.S. Gov. Res. Rep., Vol. 36, p. S-48(A), Sept. 5, 1961 PB 150 136

Thermoelectric power measurements made on the systems silver chloride + cadmium chloride, silver bromide + silver sulfide and silver bromide + cadmium sulfide, as well as the pure silver halides, in the temperature range from 100° to 400°C, are reported.

11,064 EFFECTIVE X-RAY AND CALORIMETRIC DEBYE TEMPERATURE FOR COPPER by P. A. Flinn, G. M. McManus, and J. A. Rayne (Westinghouse Res. Labs.); Phys. Rev., Vol. 123, pp. 809-812, Aug. 1961

Determination of the Debye-Waller factor for copper from x-ray intensity measurements on a single crystal over the temperature range 4.2° - 500°K is cited. From a machine calculation of the vibrational spectrum of copper the values of the specific heat and Debye-Waller factor were obtained and compared with those found by experiment. The agreement indicates that for copper the central force model with nearest-and second-neighbor interactions is adequate for the interpretation of effects depending on simple averages over the frequency spectrum.

Effect of Device Lifetime on Thermoelectric Generator Efficiency - See 11,081

11,065 A CONTRIBUTION TO THE STUDY OF THE ELECTROLYTIC PELTIER EFFECT OF THE AMALGAM SYSTEM ZINC-ZINC SULFATE [in French] by Y. Thouvenin (CNRS, Bellevue); Comptes Rendus, Vol. 253, pp. 117-119, July 3, 1961

The electrolytic Peltier effect of the amalgam system Zn-ZnS is discussed. The Peltier electrolytic molar specific heat is defined in terms of the reversible phase change of a mole of electroactive ion and of the potential difference between the two electrodes. The transfer molar specific heat is defined using the reaction absolute temperature and the reaction free chemical enthalpy. The electrodes are considered as open thermodynamic systems, and energy exchanges between the electrodes and their surroundings are taken into account in the derivations, which are based on the Lange theory. Two curves of $Zn/Zn^{++}$ Peltier specific heat in kjoules vs $\log C_{Zn}$ and vs $\log C_{Zn^{++}}$ (i.e., vs amalgam concentration and vs $Zn^{++}$ anion concentration) are presented for T = 30°C. The familiar linear plots are obtained. The normal potential of the amalgam system is derived using Nernst's law.

11,066 LONG-RANGE ORDER IN Fe-Al ALLOYS. Part II. THERMOELECTRIC POWER by G. Erez and P. S. Rudman (Israel Inst. Tech.); J. Phys. Chem. Solids, Vol. 18, pp. 307-315, Mar. 1961

The thermoelectric power, TEP, relative to copper has been measured in Fe-Al alloys. The critical temperature for the $Fe_3Al$ structure was marked by a sharp change in slope of the TEP vs temperature plot and the phase boundary was accordingly determined; for stoichiometric $Fe_3Al$, $T_c = 560 \pm 5$°C. The critical temperature of the FeAl structure was not marked by a similar change in slope; however, a change in slope of the TEP vs composition plot defines this transformation. $Fe_3Al$ order acts to increase while FeAl order acts to decrease the TEP. The results are interpreted in terms of distortion of the density of states curve of the 4s band due to the formation of new Brillouin zones accompanying ordering. The results are discussed in terms of the change on ordering of the kinetic energy of the 4s electrons as being the origin of the ordering energy for the $Fe_3Al$.

11,067 THERMOELECTRIC POWER GENERATION AND RELATED PHENOMENA (Battelle Mem. Inst.); U.S. Gov. Res. Rep., Vol. 36, pp. 89-90(A), Sept. 5, 1961 AD 258 987

High-temperature electrical measurements made on n-type GaAs-AlAs alloy specimens containing 3.8 and 7.8 mol % AlAs are discussed. An initial decrease in resistivity was observed as the temperature was increased. The higher alloys exhibited Hall coefficient-reciprocal temperature relationships similar to those observed for n-type GaAs. Thermoelectric power data suggest that the thermoelectric power of the GaAs-AlAs alloys increases with AlAs concentration. Evaluation of the solute build-up technique indicated that quartz was not a suitable material for a melt container in the preparation of Ga compounds requiring long reaction times in view of the probable contamination of the melt by Si. The thermal diffusivity of GaAs was measured as a function of temperature, and the preparation of a GaAs-AlAs alloy sample for measurement was begun. The specific heat of GaAs was measured from 0 to 350°C and found to be 0.347 joule/g-deg C.

## MECHANICAL PROPERTIES

11,068 THEORY OF THE DEFORMATION POTENTIAL FOR SEMICONDUCTORS WITH A COMPLEX BAND STRUCTURE by G. L. Bir and G. E. Pikus (Acad. Sci., USSR); Soviet Phys.-Solid State, Vol. 2, pp. 2039-2051, Mar. 1961

A theory of the deformation potential for semiconductors with a complex band structure is developed. An operator for the interaction between electrons and the long wavelength acousti-

cal and optical phonons is constructed and the transition probabilities are calculated. The general expressions obtained are used in order to calculate the matrix elements for the scattering of holes in p-type germanium.

11,069 THIRD-ORDER ELASTIC MODULI OF GERMANIUM by T. Bateman, W. P. Mason, and H. J. McSkimin (Bell Labs.); J. Appl. Phys., Vol. 32, pp. 928-936, May 1961

The six third-order elastic moduli of Ge are evaluated. The method involves measuring ultrasonic velocities in selected directions when directed static stresses are applied to the crystal. Three measurements are obtained by using hydrostatic pressures, three by using a static compression along the <110> axis with measurements being made along the <001> direction and the <1$\bar{1}$0> direction. Using the finite strain formulas of Murnaghan, the measured velocities are related to the three second-order elastic moduli and the six third-order elastic moduli for a cubic crystal. The 12 sets of measurements provide considerable overlap, and the probable errors are shown to be moderate.

11,070 LOW-FREQUENCY MEASUREMENTS ON THE BORDONI INTERNAL FRICTION PEAK IN COPPER by D. H. Niblett (Cornell U.); J. Appl. Phys., Vol. 32, pp. 895-899, May 1961

An apparatus for the measurement of the internal friction of metals over the temperature range of 4° - 300°K at a frequency of the order of 10 cps is described. The Bordoni internal friction peak was observed in pure polycrystalline copper at 62°K at a frequency of 13.4 cps. By comparison with measurements at higher frequencies, a value of 0.14 ev is deduced for the activation energy. The width of the Bordoni peak is discussed in terms of distributions of activation energies and attempt frequencies.

# SOLID STATE DEVICES

## DIODES

11,071 TWO-TERMINAL SEMICONDUCTIVE SWITCH HAVING FIVE SUCCESSIVE ZONES by J. M. Goldey (Bell Labs.); U.S. Pat. 2,980,810, Issued Apr. 18, 1961

A five-layered, two impedance level, bidirectional, semiconductor switch suitable for application in magnetic core memory systems is described. High impedance level is essentially the sum of four junctions, of which two are reversed biased. The device is triggered to the low impedance level by breaking down the reversed-biased junctions and preserving this impedance condition with a sustaining voltage. Operation with reverse polority voltage is the same.

11,072 THE EFFECT OF THE TYPE OF IONS ON THE NATURE OF CHANGES OF ELECTRICAL PROPERTIES OF SEMICONDUCTOR SURFACES PRODUCED BY IRRADIATION WITH IONS OF MEDIUM ENERGIES by M. M. Bredov, V. A. Lepilin, I. B. Shestakov, and A. L. Shakh-Budagov (Inst. Semicon., Leningrad); Soviet Phys.-Solid State, Vol. 3, pp. 195-199, July 1961

A study of changes in the current-voltage characteristics of W-Ge and W-Si point contacts, due to irradiation with atomic oxygen and molecular nitrogen ions of 5 and 10 kev energies, is discussed. There was a considerable difference between the effects of O and $N_2$ ions on the forward and reverse currents and on the rectification factor.

11,073 POINT CONTACT RECTIFIER DEVICE by A. S. Epstein (Monsanto); U.S. Pat. 2,980,833, Issued Apr. 18, 1961

Fabrication of organic point contact devices employing monomeric metal phthalocyanine, formed from tetrafunctional pyromellitonitrille, is described. The degree of p-type or n-type conductivity will vary with the excess of deficiency of the metal stoichiometrically required. A device produced from copper polyphthalocyanine, employing a point contact of gold-plated copper, gives a rectification ratio of about 3 to 1.

Five Layer Diode - See 11,071

11,074 THE TUNNEL DIODE - PHYSICAL FOUNDATIONS, MANUFACTURE AND APPLICATION [in German] by H. J. Hartmann, M. Michelitsch, and W. Steinhäuser (Standard Elect. Lorenz, Nurnberg); Arch. Elect. Uebertragung, Vol. 15, pp. 125-144, Mar. 1961

A review of p-n junctions and quantum tunnel effect theories is presented. Various methods of fabricating and mounting tunnel diodes are cited. Relationships of alloying parameters (temperature and time) and etching to electrical characteristics are shown. The static and dynamic stability conditions which must be considered in tunnel diode curcuitry are defined through use of an equivalent circuit. Typical applications in amplifiers, oscillators, and high-speed gate circuits are shown.

11,075 IRREVERSIBLE CHANGES IN THE SPACE CHARGE REGION IN DEGENERATE GaAs P-N JUNCTIONS by R. D. Gold, B. Goldstein, L. R. Weisberg, and R. M. Williams (RCA Labs.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, pp. 312-313(A), Apr. 24, 1961

The mechanism of irreversible changes in the space charge region in degenerate GaAs p-n junctions was discussed. The exponential dependence of the tunneling current through narrow p-n junctions on the width of the space charge region provides a very sensitive indication of changes in this width. The space charge region in GaAs tunnel diodes widens within hours during operation at room temperature. This is indicated by a decrease in junction capacitance, and is accompanied by an irreversible exponential decrease in peak tunneling current, together with a small decrease in valley current. These effects occur only when current flows in the forward injection region, and not when tunnel current alone is present. Temperature by itself does not cause these effects since no decrease in peak current occurs when the diode is maintained at 200°C for several weeks with no current. Therefore, neither thermal diffusion or field-enhanced diffusion can alone account for the redistribution of charge in the depletion layer. The measured junction temperature for currents sufficient to produce degradation (decrease in peak current) is considerably less than 200°C. However, the rate of degradation with such a current can be increased by more than two orders of magnitude for a temperature change from 25° to 150°C.

11,076 INVESTIGATIONS OF THE CURRENT-VOLTAGE

CHARACTERISTICS OF GERMANIUM ESAKI DIODES by M. I. Nathan (IBM); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 106(A), Mar. 20, 1961

The current-voltage characteristics of Sb-doped and As-doped Ge tunnel diodes were discussed. Simple tunneling theory predicts that $\ln(J/V)$ ($J$ = current density, $V$ = reverse bias) varies linearly with $V$ for $ev \ll E_g$. Antimony-doped diodes which have phonon assisted current predominant at 4°K were found to exhibit such a dependence at room temperature for $V \lesssim 0.1$ v. Moreover, in agreement with simple theory, the slopes $S$ of the $\ln(J/V)$ plots for different diodes were proportional to $\ln J_p$ (peak current density) and hence to the tunneling exponent $\theta$. However, the constant of proportionality $\gamma (= \theta/S)$ is $\sim 40$ per cent larger than the calculated value, if a constant field through the junction is assumed. It was shown that, if the variations of field through the junction are considered, such larger values of $\gamma$ can be obtained. In arsenic-doped diodes the onset voltage for tunneling to the (000) conduction band minimum was also observed as a function of arsenic concentration up to $4 \times 10^{19}/cm^3$. It was found that the energy separation of the n-side (000) minimum and the Fermi level cannot be less (by more than 0.02 v) than the value expected on the basis of data obtained in pure material.

11,077 ELECTRON BOMBARDMENT DAMAGE IN SILICON ESAKI DIODES by R. A. Logan, W. M. Augustyniak, and J. F. Gilbert (Bell Labs.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 206(A), Mar. 20, 1961

The effects of bombardment and the properties of annealing of radiation damage in Si Esaki diodes in relation to the specific donor in the n-type region of the diode were discussed. The average bombardment dose of 1-Mev electrons/$cm^2$ needed to increase the excess current density by 1 amp/$cm^2$ at a bias of 0.3 v was $1.2 \times 10^{16}$ for P-doped diodes and $0.8 \times 10^{16}$ for Sb- or As-doped diodes. The increase in excess current observed at room temperature was the same for bombardments at 78° or 300°K. Upon annealing in an inert atmosphere, at temperatures in the range of 300° to 400°C, the bombarded diode was restored to its original characteristics. The annealing kinetics for the As or Sb diodes were similar to those observed in As-doped Si in lifetime studies, while the P-doped diodes annealed more rapidly. Structures observed in the I-V characteristic during the annealing were also discussed.

11,078 INDIUM ARSENIDE TUNNEL DIODES by H. P. Kleinknecht (RCA Labs.); Solid-State Electronics, Vol. 2, pp. 133-142, Mar. 1961

Tunnel diodes made by alloying In-Cd and In-Zn dots on InAs crystals which had been doped with $2 \times 10^{16}$ to $6 \times 10^{18}$ Te atoms/$cm^3$ are discussed. The resulting I-V characteristics vary with doping level and temperature from classical p-n curves to Esaki curves of 10:1 peak to valley current ratios. The best ratios at room temperature are about 2:1. Good units with high current density do not show any structure indicative of phonon participation. However, lower-current units do show two conductance minima in the rising part of the forward characteristic at 4°K. The high-current units also show a different temperature dependence of the peak current and of the peak voltage than those of lower current density. This leads to the tentative conclusion that the characteristics of the low-current units are determined by phonon-assisted tunneling, while in the high-current units the direct tunneling process is dominant. In the I-V characteristic of units made from low-doped material an interesting cusp structure is found. This resembles the "phonon" structure above, but is dependent on the surface condition of the diode. A measurement of the rise time of a switching pulse across the diode proved to be limited by the circuit to $10^{-9}$ sec. This and other indirect measurements allow an estimate of a gain-bandwidth product, for the faster diodes, of 3 kMc.

11,079 ANALYSIS OF P-N JUNCTIONS AND JUNCTION DEVICES BY A FLUX TECHNIQUE by J. P. McKelvey (Westinghouse Res. Labs.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 313(A), Apr. 24, 1961

A novel technique of analysis of excess carrier behavior in semiconductors, based upon conservation of carrier fluxes, after allowing for generation and recombination, was described. The technique is applicable to semiconductor p-n junctions and simple devices. It is assumed that the junction injects a flux of excess minority carriers into the bulk material on either side, and that the flux source strength is proportional to $\exp(eV/kT)$. In the case of the planer p-n junction in an infinite semiconductor, the usual exponential current-voltage dependence is obtained, but a more general expression for the saturation current than that obtained from conventional diffusion theory is exhibited. In particular, it was shown that for sufficiently low carrier lifetime in the bulk material, the saturation current becomes independent of lifetime. The application of the method to a simple photovoltaic cell was also discussed. Here again the current-voltage dependence (which is related to the boundary condition at the junction rather than to diffusion and recombination phenomena in the bulk) is unaltered, but modified expressions for saturation and generation currents were obtained. Applicability of the method is currently limited to steady-state one-dimensional situations.

Effect of Magnetic Field on Tunneling - See 11,015

Exponential Dependence of Tunneling Current on Width of Space Charge Region - See 11,075

11,080 ON THE NATURE OF THE EXCESS CURRENT IN TUNNEL DIODES by T. P. Brody (Westinghouse Res. Labs.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 105(A), Mar. 20, 1961

Tunneling between impurity band states of the heavily doped p and n regions as a mechanism of "excess current" observed in tunnel diodes was suggested. Density-of-states curves were constructed, based on several different models of impurity bands, and the tunneling current between such bands was computed and compared with experiment. The effect of different base materials and impurities on the excess current was discussed in terms of the impurity band model. The possibility of obtaining information about impurity band structure from tunnel diode measurements was considered. The model also postulates Fermi levels which fall inside the intrinsic energy gap, despite the large degeneracy. Experimental evidence supporting this aspect of the model was summarized.

Switching Characteristics of Semiconductor Devices - See 11,092

11,081 AN ANALYSIS OF THE PERFORMANCE OF THERMOELECTRIC DEVICES MADE FROM LONG-LIFETIME SEMICONDUCTORS by R. N. Hall (GE Res. Lab.); Solid-State Electronics, Vol. 2, pp. 115-122, Mar. 1961

The performance of an ohmic-n-p-ohmic junction rectifier made

from a long-lifetime semiconductor is analyzed as a thermoelectric generator and as a refrigerator. An upper limit to the efficiency of this device is shown to be inferior to that of a conventional (zero-lifetime) thermoelement. Arguments are presented to show that any semiconductor device, in which non-equilibrium concentrations of minority carriers play a part in determining the electrical characteristics, will have a poor thermoelectric efficiency. The generalization that lifetime is not an important material property for semiconductor thermoelements is made.

11,082 FLUCTUATION NOISE IN SEMICONDUCTOR SPACE-CHARGE REGIONS by L. J. Giacoletto (Ford); Proc. IRE, Vol. 49, Part 1, pp. 921-927, May 1961

An analysis of basic noise in diode junctions is presented. This basic noise mechanism is due to fluctuations in the ionization state of the impurity atoms which occur at random relative to the probability of ionization, $w = n_D^+/n_D$. In an n-type semiconductor, a neutral impurity that suddenly becomes ionized releases a mobile electron whose movement forms a noise current pulse; similarly for the elemental deionization event. The net result is a short-circuited noise current for which a formula is derived. Using typical numbers, this formula indicates that the fundamental noise associated with a 0.3 μfd depletion layer capacitance at 100 Mc is equivalent to the thermal noise of a 6 ohm series resistor at 40°K and a 0.1 ohm series resistor at 300°K. Experimental verification of this type of noise is not known. When it is observed experimentally, a new method for evaluating some of the basic properties of semiconductors will be available, and computations of minimum noise factor of parametric amplifiers will be possible.

11,083 SEMICONDUCTOR DEVICES AND METHODS OF MAKING THEM by D. A. Jenny and J. J. Wysoki (RCA); U.S. Pat. 2,979,428, Issued Apr. 11, 1961

Fabrication techniques involving diode and transistor structures of group III-V semiconductor compounds are discussed. Specific devices cited are a diode and an n-p-n transistor fabricated from monocrystalline GaAs. Dots of zinc, cadmium, or mercury are employed as p-type agents; sulfur, selenium, or tellurium as n-type agents. Ohmic contacts are provided by alloying pellets of aluminum, gallium, indium, or lead to the element areas.

Miniature Semiconductor Device Packages - See 11,097

11,084 HIGH VOLTAGE SEMICONDUCTOR RECTIFIER by C. E. Maiden (Pacific Semicon.); U.S. Pat. 2,979,645, Issued Apr. 11, 1961

A high voltage rectifier assembly with a voltage rating in excess of 1,500 volts is described. Semiconductor rectifiers, housed in conventional glass-to-metal seal packages, are placed in a side by side orientation and are electrically and mechanically connected in series. The resulting series diode sub-assembly is then placed in a thin walled plastic tube. The tube is filled with resin and caps are inserted at the ends to complete the device.

11,085 DIODE SPIDER ASSEMBLY by P. Eggers (U.S. Navy); U.S. Pat. 2,980,828, Issued Apr. 18, 1961

A helical diode assembly for compact high voltage rectifier networks is described. The assembly provides easy accessibility to rectifier components for repair or replacement and adequate thermal dissipation for heat generated by the components.

## TRANSISTORS

11,086 CONCERNING THE DESCRIPTION OF LIFE CHARACTERISTICS IN THE MANUFACTURE OF TRANSISTORS [in German] by C. Villalaz (Philips, Zurich); Arch. Elekt. Uebertragung, Vol. 15, pp. 181-186, Apr. 1961

The design interpretation, and application of transistor life tests are discussed. Detailed investigation concerning the life characteristics of transistors inevitably leads to a compromise between information depth and information survey. By fixing the limits of the information range as well as by subdivision into simplified single complexes such a compromise solution is attempted. Among other problems the schematic description of any form of life test curves by a simple symbolism is discussed. The principle of superposition of dimensionless distributions in certain test-working instants with the absolute distributions of the starting values is explained.

11,087 ALPHA CUTOFF FREQUENCY OF JUNCTION TRANSISTORS by J. Lindmayer and C. Wrigley (Sprague Electric); Solid-State Electronics, Vol. 2, pp. 247-258, May 1961

The alpha cutoff frequencies of drift and diffusion transistors are analyzed and approximated by simple analytical expressions. The alpha cutoff frequency is determined in terms of the three major contributions: base-region transport cutoff, emitter cutoff due to the emitter capacitance, and the collector cutoff due to the base resistance and the collector capacitance. Denoting the respective cutoff frequencies by $\omega^*_{ca}$, $\omega_E$ and $\omega_c$, and the resulting cutoff frequency by $\omega_{ca}$, it is found by computation that $\frac{1}{\omega_{ca}} = \frac{1}{\omega^*_{ca}} + \frac{1}{\omega_E} + \frac{2}{\omega_c}$. In addition, a new expression is given for the base transport cutoff. The dependence of the frequency cutoff on the emitter current is also discussed for the current range where the built-in-electric field is partially washed out by the high concentration of minority carriers injected into the base. A calculation is presented for the current level at which there is a maximum in the alpha cutoff. Experimental data are compared with the calculations.

Effect of Ion Bombardment on the Electrical Properties of Transistor Point Contacts - See 11,072

Point Contact Devices Employing Organic Semiconductors - See 11,073

11,088 NOTES ON THE THEORY OF FOUR-LAYER SEMICONDUCTOR SWITCHES by A. K. Jonscher (GE Ltd.); Solid-State Electronics, Vol. 2, pp. 143-148, Mar. 1961

The effects of transverse base resistance on three-terminal operation of p-n-p-n switches are discussed. The discussion begins with the accepted theory of four-layer devices, and includes transient response to two- and three-terminal on- and off-switching.

11,089 HIGH CURRENT NPNP SWITCH by F. S. Stein and E. W. Torok (Westinghouse); U.S. Pat. 2,980,832, Issued Apr. 18, 1961

Fabrication of a three terminal, multi-junction, semiconductor switch, with breakdown voltage controlled by base current, is

described. A silicon n-p-n-p switch is cited. P-type regions are formed on the n-type wafer by diffusion; a gold-antimony foil is then fused on one p-type region to form the emitter. Typical characteristics of the device are breakover voltages of up to 900v, breakover currents of from 0.1 to 25 ma., base firing currents of from 5 to 300 ma., forward voltage drop of 1.0 to 1.5v at 20 amps, delay and rise times of a few tenths of a μsec at 1 amp, and recovery time of 10 to 20 μsec at one amp.

11,090 THE HIGH-INJECTION-LEVEL OPERATION OF DRIFT TRANSISTORS by J. Lindmayer and C. Wrigley (Sprague Electric); Solid-State Electronics, Vol. 2, pp. 79-84, Mar. 1961

An analysis of the minority-charge distribution in the base region of the drift transistor by a one-dimensional theoretical model is presented. The analysis results in an Abel-type differential equation which has no analytical solution. It is possible to compute the charge distribution, and, by normalization, it can be done with only two parameters for an exponential impurity distribution. The stored charge and the transit time are given as functions of the injection level. The overall time constant of the drift transistor shows a minimum at a particular current density; a good analytical approximation for this current density is developed.

11,091 THERMAL TRANSIENT EFFECTS ON JUNCTION TRANSISTORS by T. C. Verster (Natl. Phys. Res. Lab., Pretoria); J. Electronics Control, Vol. 10, pp. 191-196, Mar. 1961

Experimental evidence to show that the collector leakage current $I_{co}$ of junction transistors contains a component which does not respond immediately to a step change in temperature, but subsequently undergoes a slow growth, both for positive and negative temperature changes, is presented. This occurs even in transistors normally not subject to growth of excess leakage current at constant room temperature. Following a large temperature excursion, recovery at room temperature is slow, being of the order of days. The practical significance of this effect on the use of transistors in dc amplifiers, thermometers and as sensing elements, is illustrated with measurements on one transistor and a temperature-compensated dc amplifier. It is shown that the latter case yields good compensation over a wide temperature range only when the temperature transient extends over more than a day.

11,092 MEASUREMENT OF THE SWITCHING CHARACTERISTICS OF SEMICONDUCTORS [in German] by L. Starke; Elektronik, Vol. 10, pp. 45-46, Feb. 1961

Measuring techniques to determine the switching characteristics of semiconducting devices for applications in high speed computing machinery are discussed. A brief summary of the reasons for greater machine speed is given.

Group III-V Alloyed Junctions - See 11,083

Fabrication of Transistors by the Diffusion of Impurities along Grain Boundaries - See 11,100

11,093 MICROMASKING FOR CHEMICAL ETCHING OF SEMICONDUCTORS by S. Denda (Electrotech. Lab., Tokyo); Solid-State Electronics, Vol. 2, p. 69(L), Jan. 1961

A method for producing mesas down to 30μ or less in diameter in diffused transistors and diodes, without utilizing photomasking techniques, is described. A thin thread of picein, black wax used for sealing vacuum systems, is positioned by means of a mechanical holder so that it touches the semiconductor surface. The tip of the thread is melted by passing a current pulse through a platinum heater supporting the semiconductor; the masked pellet is then etched. The height of the mesa is limited to one third the diameter to prevent removal of the mask during the etching. The mask is dissolved by benzol after the etching.

11,094 JUNCTION TRANSISTOR by W. Shockley; U.S. Pat. 2,980,830, Issued Apr. 18, 1961

Junction transistors with low base resistances having relatively high alpha cutoff frequencies and/or high power capacities are described. High conductance ribs are employed in a web-rib base structure to effect a reduction in the $C_cP_b$ product by reducing base resistance; cutoff frequency, and inverse function of this product, is increased. Alternately, a rib structured device offers larger dimensions and better power-handling capacities than a conventional base structured device with the same $C_cP_b$ product. Various fabrication schemes, employing multiple diffusions, lapping, polishing, etching, photoengraving, and similar techniques, are cited and several devices with web-rib base configurations are discussed.

Anodic Sectioning of Diffused Junctions - See 10,937

Low-Ohmic Contacts to Crystals - See 10,959

11,095 DIFFUSED TRANSISTOR AND METHOD OF MAKING by B. Cornelison and E. Wolff, Jr. (Texas Instr.); U.S. Pat. 2,979,429, Issued Apr. 11, 1961

A method of fabricating an intrinsic layer diffused junction transistor is described. A single step diffusion technique, whereby three impurities of predetermined conductivity type are introduced into a semiconductor body, is utilized to produce the p-n-i-p or n-p-i-n structure desired. A specific system to produce a Ge n-p-i-n device, employing impurities of In, Ga, and As, is cited.

11,096 MEANS FOR REDUCING SURFACE RECOMBINATION by K. Lehovec and R. Zuleeg (Sprague); U.S. Pat. 2,980,831, Issued Apr. 18, 1961

A method for the reduction of surface recombination of minority carriers in a semiconductor is described. Surfaces where recombination may occur are covered with a coating which has a high minority carrier injection efficiency and is electrically insulated from the device electrodes. Layers of indium doped p-type material on n-type Ge bodies are cited as specific examples and a photodiode and transistor utilizing such layers are discussed.

11,097 SEMICONDUCTOR FABRICATION by J. F. McMahon, Jr., F. K. Clarke, and H. K. Ishler (Philco); U.S. Pat. 2,985,806, Issued May 23, 1961

A semiconductor package structure of reduced size and weight is described. Electrical contact to the interior of the package is provided by a coplanar array of radially disposed, ribbon-like leads hermetically encased in a common lamina of glass. The radial length of the seal between leads and glass insures mechanical strength and a hermetic bond. Encapsulated transistors employing this structure have been fabricated with an overall height of 30 mils.

11,098 DC CHARACTERISTICS OF THE UNIPOLAR TRANSIS-

TOR WITH CONSIDERATION OF RESISTANCE LOSSES [in German] by A. H. Frei (Princeton U.); Arch. Elekt. Uebertragung, Vol. 15, pp. 161-165, Apr. 1961

A theoretical formula for the dc drain characteristics of the unipolar field-effect transistor is derived. A uniform distribution of the space-charge field in the channel is assumed, rather than a step between space-charge region and conduction region. The effect of non-zero drain and source resistances is also included. Agreement between theoretical and measured values on actual field-effect transistors is much better than for the hitherto known formulas.

11,099 SEMI-CONDUCTOR DEVICES FOR RECTIFYING AND CLIPPING LARGE ELECTRICAL CURRENTS by S. Teszen; U.S. Pat. 2,980,809, Issued Apr. 18, 1961

Devices capable of functioning either as rectifiers or as automatic current clippers, employing unipolar field-effect transistors as components, are described. In rectifier applications the field-effect transistor is cut off on every other half wave by biasing the gate with voltage pulses of duration and spacing equal to the half wave and of amplitude equal or greater than the pinch-off voltage. Current surge on short circuits is prevented by complementary biasing of the gate. In current clipping applications the gate is charged with an in phase voltage pulse when the predetermined current limit is reached.

11,100 SEMICONDUCTOR DEVICE AND METHOD OF MAKING THE SAME by W. Shockley; U.S. Pat. 2,979,427, Issued Apr. 11, 1961

Semiconductor devices fabricated by the diffusion of impurity atoms along grain boundaries are described. Small diffused structures are obtained in the interior of nearly intrinsic material to provide high frequency field effect and analog transistors. Under operating conditions, the nearly intrinsic material acts as an insulating dielectric layer.

## MAGNETOELECTRIC DEVICES

11,101 THE DESIGN AND PERFORMANCE OF A HALL-EFFECT MULTIPLIER by R. P. Chasmar, E. Cohen, and D. P. Holmes (Metropolitan-Vickers); Proc. IEE, Vol. 106B, Suppl. No. 16, pp. 702-705, 746-747, 1959

The construction of a Hall effect multiplier is described. Design features such as linearity, frequency response, temperature stability, and circuit considerations are discussed. Applications of the device, such as applications in analog computers, are suggested.

11,102 FOUR-TERMINAL ANALYSIS OF THE HALL GENERATOR by D. L. Endsley, W. W. Grannemann, and L. L. Rosier (U. New Mexico); IRE Trans., Vol. ED-8, pp. 220-224, May 1961

The four-terminal parameters of the Hall generator are derived and then used to develop expressions for input impedance, output impedance, current gain, and voltage gain. The theoretically determined expressions are then verified for a Hall generator using indium antimonide. The four-terminal equations are given as a function of conductivity, Hall constant, temperature, magnetic field, and dimensions of the material. Thus, the designer may use these expressions in the application of Hall effect devices.

11,103 MEASUREMENT CONCERNING THE FREQUENCY DEPENDENCE OF THE GAUSS EFFECT IN VARIOUS SEMICONDUCTORS UP TO 2000 MHz [in German] by M. J. O. Strutt and F. K. von Willisen (Eidgen. Tech. Hochsch., Zurich); Arch. Elekt. Uebertragung, Vol. 15, pp. 25-32, Jan. 1961

Measurements of the magnetoresistance of Corbino discs of Ge, InSb, and InAs are discussed. The operational range of the measurements include frequencies from 0 - 2,000 Mc, temperatures from 140° - 270°K and flux densities up to 10,000 gauss. A pronounced frequency dependence was found above 30 Mc. This frequency dependence was calculated on an approximate basis using Maxwell's equations, and the results are in qualitative agreement with measured curves. The phenomenon is attributed to a special kind of "skin effect."

## PHOTODEVICES

11,104 DEPENDENCE OF NOISE EQUIVALENT POWER ON AREA IN PbS, PbSe, and PbTe by T. Limperis and W. L. Wolfe (U. Michigan); 1961 Spring Mtg. Opt. Soc. Am.

The results of a statistical study of how the noise equivalent power (NEP) changes with area in PbS, PbSe, and PbTe films were discussed. Curves of log NEP vs log A were plotted and n in the equation, log NEP = n log A + log K, was determined; n is 0.49 for PbS, 0.60 and 0.59 for PbSe, 0.53 for PbTe for a chopping frequency of 90 cps, and 0.46 for a chopping frequency of 800 cps. The results of this study agree with the theory which predicts that n is 0.50 a square-root-of-area relationship.

11,105 TRANSIENT PHOTOVOLTAIC RESPONSE OF DIFFUSED JUNCTION SILICON PHOTODIODES by T. E. Hartman (Texas Instr.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 107(A), Mar. 20, 1961

The results of an experimental and theoretical study of the transient photovoltaic response of diffused junction Si photodiodes were discussed. The study pertained to a thin p-type layer diffused in an n-type wafer illuminated on the p-type surface with intrinsic light. An exact solution for the transient response of the photocurrent at the junction shows that the rise time is limited by minority carrier storage. Expressions for the external photovoltage rise and fall times indicate that, in general, the rise time at room temperature with no external bias depends on the light intensity as well as the load resistance, while the fall time depends only on the load resistance. Previous attempts by others to show experimental agreement with theory have not been completely satisfactory. Some of the experimental difficulties have been overcome by using an extremely fast light chopper. Rise- and fall-time measurements made on 10 Si photodiodes (TI type LS222) are in very good agreement with analysis. Impedance measurements which were important in showing the effect of load resistance on rise time were also discussed.

11,106 PHOTORECTIFIER BASED ON A COMBINATION OF A PHOTOCONDUCTOR AND AN ELECTRET by J. G. van Santen and G. Diemer (Philips); Solid-State Electronics, Vol.

2, pp. 149-156, Mar. 1961

The preparation and characteristics of a photorectifier formed by embedding photoconductive layers of CdS powder in an electret (glass-enamel) are discussed. The mechanism of the rectification is described with reference to the photocurrent through the powdered CdS layer. The construction of a cross-bar system based on this new type of photorectifier is discussed.

Wavelength and Temperature Dependences of Photovoltage in ZnS - See 11,056

Method for Analysis of Photoresponse of Photovoltaic Cells - See 11,079

11,107 INTERFERENCE FILTERS FOR THE 8-13 μ ATMOSPHERIC WINDOW by A. F. Turner and R. Walsh (Bausch and Lomb); 1961 Spring Mtg. Opt. Soc. Am.

Vacuum-deposited multilayer interference filters suitable for isolating broad bands of radiation in the region of the 8-13 μ atmospheric window were described. For example, the spectrophotometric characteristics of a 9-layer flat-topped band-pass filter on an antireflected Ge substrate utilizing alternate quarterwave films of PbTe and half-wave films of ZnS are: average T = 90%, half-width 3 μ, width at 1% T 4.5 μ, background T = 0.3%. Such a filter centered at 10 μ rejects from 12.5 to 19 μ on one side of the passband and from 8 to 6.8 μ on the other. Shorter wavelengths may be eliminated by an auxiliary antireflected InSb plate, and longer wavelengths by a plate of $BaF_2$. Variations of these characteristics can be obtained by substituting films of other materials and by employing different numbers of layers.

11,108 THE USE OF PRESSED DISCS OF KCl IN ULTRAVIOLET SPECTROPHOTOMETRY by V. A. Shlyapochnikov and V. . Slovetskii (Acad. Sci., USSR); Optics and Spectrosc., Vol. 10, p. 132 (L), Feb. 1961

A method of preparing optically transmitting KCl discs for use in the ultraviolet region is discussed. These pressed discs are used in place of crystals due to the difficulty of growing single crystals with a cross section of the order of 0.001 mm or less. Spectra recorded with the discs indicate they possess good transmission properties.

## THERMAL DEVICES

11,109 A POSITIVE TEMPERATURE COEFFICIENT OF RESISTANCE THERMISTOR - ITS CHARACTERISTICS AND APPLICATIONS by Y. Ichikawa and W. G. Carlson (Westinghouse); Am. Ceram. Soc. Bull., Vol. 40, p. 211 (A), Apr. 1961

The electrical properties and applications of thermistors prepared from valence-controlled ferroelectric solid solutions were discussed. The devices exhibit large positive temperature coefficients of resistance in a temperature region defined by the tetragonal-cubic phase transition of the ferroelectric solid solution.

Thermoelectric Power of Silver Halides - See 11,063

Thermodynamics of Thermoelectric Cooling - See 11,062

Analysis of Semiconductor Thermoelectric Generators - See 11,081

## FERRITE DEVICES

11,110 INVESTIGATION OF MICROWAVE DUPLEXER SWITCHING MECHANISMS by S. Takeda, M. Roux, et al. (U. Illinois); U.S. Gov. Res. Rep., Vol. 36, p. S-81 (A), July 5, 1961 PB 154 397

Research on semiconductor behavior in high level microwave fields carried out using resonant cavity techniques at eight millimeter wavelengths is discussed. The measurements were performed with a new cavity with measured characteristics in closer agreement with theory than before and in a redesigned microwave circuit employing a new magnetron modulator. The results of measurements on transmission through vacuum evaporated thin films of indium antimonide are presented.

11,111 RECTANGULAR FERRITE TOROIDS AS SWITCHING ELEMENTS [in German] by W. Hilberg (Telefunken, Ulm); Arch. Elekt. Uebertragung, Vol. 15, pp. 145-152, Mar. 1961

An approximate analytic relationship between domain wall displacement and remagnetization in rectangular hysteresis loop ferrites is derived. The discussion is restricted to rectangular ferrites and thin strips in which the eddy current effect can be neglected for the remagnetization times under consideration. The relationship is applied to such toroidal core arrangements where the applied field acts in a tangential direction so that shape anisotropies need not be considered. A determination of remagnetization vs time is carried out for some cases of practical importance where a load is given by resistances, inductances and additional cores. The energy conditions are discussed by reference to a typical resistive load.

11,112 MAGNETIC PROPERTIES OF A 97 Fe-3 Ni THIN FILM ELECTROPLATE by H. J. White and A. J. Kolk (Natl. Cash Register); J. Electrochem. Soc., Vol. 108, p. 173 C (A), Aug. 1961

Investigations of the effects of various fabrication parameters on the magnetic properties of a thin film electroplate used in the NCR "Rod" computer memory element were reviewed. The "Rod" employs a 97 Fe3 Ni alloy deposited on a silvered-glass cane or a BeCu wire of approximately 10 mil diameter. The physical condition of the surface of the silver or the BeCu has been found to be of great importance in determining the magnetic properties of the overplate. The effects of current density, pH, plate thickness, and magnetic field applied during plating have been investigated. Unlike permalloy, the magnetic properties were not found to be sensitive to minor variations in alloy composition and were only slightly affected by the level of stress in the plate. The high-speed magnetic switching coefficient of the "Rod" is of a magnitude normally associated with the incoherent rotation mechanism.

Ferromagnetic Powders for Memory Elements - See 10,942

Gyromagnetic Materials - See 10,947

## MASERS AND LASERS

11,113 ELECTRON NUCLEAR DOUBLE RESONANCE EFFECTS IN GASH by O. Risgin and G. Makhov (U. Michigan); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 118 (A), Mar. 20, 1961

The electron nuclear double resonance effects in GASH were discussed. Electron nuclear interaction existing in GASH

assumes two forms. First, the usual decrease has been observed of the EPR absorption signal with application of NMR power at frequencies of $Al_{27}$, proton, etc. resonance. Secondly, with GASH operated as a maser, there exists an interaction between the maser output and applied RF power of the order of megacycles. This interaction manifests itself as converter action; i.e., several orders of sidebands appear about the center frequency. An interpretation of the above phenomenon is based on experimental evidence that the EPR line of GASH is inhomogeneously broadened to a substantial degree. The application of nuclear frequency RF power induces hyperfine transitions, and connects the normally isolated spin packets existing within the linewidth. In the case of the maser oscillator this results in the appearance of secondary oscillators which may be regarded as sidebands. Oscillation occurs at the center of the gain envelope; hence, sidebands are symmetric. Conversely, an external signal can be positioned anywhere within the envelope; hence, a single sideband may be obtained.

Optical Maser Effects in $CaF_2:Sm^{++}$ - See 11,047

11,114 THEORY OF MASERS FOR HIGHER FREQUENCIES AND ITS APPLICATION TO A MICROBEAM ELECTRON ACCELERATOR by K. Shimoda (U. Tokyo); 1961 Spring Mtg. Opt. Soc. Am.

Some general problems encountered in the maser-type generation and amplification of infrared or optical radiation were discussed. Threshold conditions of oscillation for a beam maser, a solid-state maser, and a gas maser were obtained from a unified theory. Powers and coherence of output radiations were calculated. Among many possible applications of the extremely high brightness temperature and the radiation density obtainable with the optical maser, a high-energy electron accelerator was proposed. A cylindrical tube of maser material (ruby, for example) is pumped through an interference filter coated on its outer surface and operated on a $TM_{ONM}$ type mode so that the phase velocity along the axis may match the electron velocity. Selection of this particular mode might be obtained by a mode-selective layer covered on the inner surface of the cylinder. Optical peak power output of 10 kw/cm$^2$ should allow acceleration of more than 100 Mev when the dimension of the maser is several centimeters.

11,115 LIMITS ON DIRECTIVITY AND INTENSITY OF THE OUTPUT OF AN OPTICAL MASER by R. D. Haun, Jr. and R. C. Ohlmann (Westinghouse Res. Labs.); 1961 Spring Mtg. Opt. Soc. Am.

The conditions for damping the undersired plane-wave modes in a rectangular maser enclosure were discussed. Expressions which relate the maximum directivity of the output to the dimensions of the structure were obtained. A relationship of the output intensity as a function of the absorbed pump power and the material and structure parameters was derived.

11,116 STUDIES OF THE EMISSION FROM A PULSED RUBY OPTICAL MASER by R. J. Collins and D. F. Nelson (Bell Labs.); 1961 Spring Mtg. Opt. Soc. Am.

The radiation output of a ruby optical maser under various conditions of temperature reflectivity of end coating, and chromium content was studied. Measurements of the output power level, threshold pumping power, relaxation oscillations, and coherence, were reported. One of the common properties of the pulsed optical masers reported has been the occurrence of relaxation oscillations. It was suggested that these oscillations reflect fluctuations in the population of the upper maser level caused by a difference in the simulated and spontaneous lifetimes. By lowering the temperature of ruby optical masers, the oscillations have been suppressed completely. Through a decrease in temperature and by an optimum choice of end coating output power levels of ~ 10 kw were maintained for ~ 200 μsec. Coherence measurements were made using 2 slits placed in the end coatings by examining the interference patterns which are produced. In a 0.200 in diameter ruby rod, coherence over distances ~ 0.020 in were observed. Photographs taken of the end of the rods during maser action showed that only filaments ~ 0.020 in undergo maser action.

11,117 GAIN-BANDWIDTH IN OPTICAL MASER AMPLIFIERS AND OSCILLATORS by R. C. Ohlmann and R. D. Haun, Jr. (Westinghouse Res. Labs.); 1961 Spring Mtg. Opt. Soc. Am.

An analysis intended as a heuristic guide for considerations of regenerative gain and of bandwidth narrowing in optical maser amplifiers and oscillators was presented. By starting from the net rate of creation of photons in each mode of the maser enclosure, an expression for the steady-state gain of an optical maser amplifier was derived. The limiting case when the gain of the amplifier is large enough for spontaneous oscillations to occur has been analyzed, and an expression for the bandwidth of such oscillations was obtained.

11,118 THEORY OF QUANTUM OSCILLATORS IN A MULTIMODE RESONATOR by W. G. Wagner and G. Birnbaum (Hughes Res. Labs.); 1961 Spring Mtg. Opt. Soc. Am.

The spectrum of power radiated by a solid-state optical maser in steady-state operation was obtained. Each atomic system was considered to be a source of randomly fluctuating dipole moment which drives every mode of the cavity. The nonlinear behavior of the collection of atomic systems has been treated in such a way that a detailed examination of the distribution of power in the various modes is possible. The theory was outlined and a number of examples discussed which show how critically dependent on the relative loss rates of the various modes are the characteristics of the output from a multimode oscillator. An interesting result of this calculation is the appearance in some cases of an abrupt transition as the pumping power is increased. Above this point a large fraction of energy resides in a very small number of modes which have the lowest loss rates and are closest to the atomic resonance. Another case also was presented which does not have this feature, but which is likely to be of more use in analyzing the behavior of a real optical maser. Some experimental results were interpreted on the basis of this model.

11,119 OPTICS OF RADIATION FROM OPTICAL MASERS by J. E. Rosenthal (Bramley Consultants); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 298(A), Apr. 24, 1961

The problems associated with the in-phase radiation from optical masers were discussed. The method previously suggested for transmitting information assumed that the cross section of a coherent beam with a wavefront planar at emission could be magnified by an optical system with the following conditions being satisfied: the radiation remains coherent and the wavefront at the locus of the counter part of the original source is

planar. The validity of this premise is discussed and in particular the conditions imposed on an optical system so that a coherent parallel beam of area A and divergence angle α can be transformed into a beam of area $f^2A$, $f>1$, and divergence angle $\alpha/f$. The problem is complicated by the high-energy density of the light beam since the photon density in the ruby is comparable to the impurity density in high-resistance Si. With the available maser output power, the electrical intensity calculated from Poynting's equation may exceed 2 kv/cm. This would severely perturb the energy band scheme of the medium used in the optical system and cast doubt on the applicability of the first order dispersion theory.

11,120 PHOTON DEGENERACY IN LIGHT FROM OPTICAL MASER AND OTHER SOURCES by L. Mandel (U. Rochester); J. Opt. Soc. Am., Vol. 51, pp. 797-798 (L), July 1961

The photon degeneracy, δ, of optical masers various light sources is discussed. If δ represents the average number of photons in the same quantum state, for black body radiation, $\delta = 1/[\exp(h\nu/kT)-1]$, according to the Einstein statistics. For visible radiation at temperatures of the order of 3000°K, δ is less than unity, and typically in the $10^{-3}$ to $10^{-4}$ range. Hence most conventional light sources such as incandescent radiators and discharge tubes may be thought of as incoherent scatters. For the optical maser, however, $\delta = 10^7$ and one gas optical maser reported recently shows a δ of $10^{12}$, suggesting that these light beams exhibit good wave-like characteristics.

11,121 POSSIBLE USE OF $\overline{F}_2$ CENTERS IN LiF AS A RASER by M. L. Narchal and W. A. Barker (St. Louis U.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 298(A), Apr. 24, 1961

Additional studies of the paramagnetic resonance absorption spectrum of $\overline{F}_2$ centers produced at liquid $N_2$ temperatures by the x-radiation of LiF were discussed. A detailed theoretical analysis of the population distribution of this system was performed by the method of partial distributions. It was assumed that one or another of the paramagnetic transitions is saturated by a microwave pump of $f_p = 9.5$ kMc/sec or 30 kMc/sec. Population inversion among levels designated by different values of $m_I$ but the same value of $m_s$ was found in several cases. The material appears to be suitable for RASER action. As a result of the magnitude and anisotropy of the hyperfine structure, the proposed amplifier should have a signal frequency in the range between about 100 and 1000 Mc/sec.

## OTHER SOLID STATE DEVICES

11,122 SEMICONDUCTING STRESS TRANSDUCERS UTILIZING THE TRANSVERSE AND SHEAR PIEZORESISTANCE EFFECTS by W. G. Pfann and R. N. Thurston (Bell Labs.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 303(A), Apr. 24, 1961

The principles of a varied group of new semiconducting, piezoresistive stress and strain transducers were discussed. These devices have in common the utilization of the transverse or shear piezoresistive effect. One group of devices consists of gauges in the form of a thin rectangular sheet which is bonded to the test piece, and whose resistance change can be expressed as a simple function of the principal stresses in the test piece. Two special gauges in this group were described. In one, the resistance change is proportional to the sum of the principal biaxial stresses for any orientation of the gauge on the test piece; in the other, the resistance change is proportional only to longitudinal stress components, being independent of transverse stress components. A four-terminal gauge for complete determination of biaxial stresses, full-bridge gauges made from a single crystal, load cells of low compliance, new torque transducers, and diffusion techniques for making some of the foregoing were described. The devices were illustrated in terms of Ge and Si, but extension to other semiconductors is straightforward.

11,123 DEMAGNETIZATION OF TWISTOR BITS by W. A. Barrett (Bell Labs.); J. Appl. Phys., Suppl. to Vol. 32, pp. 35S-36S, Mar. 1961

Measurement of the demagnetization fields in twistor wire devices is discussed. Storage of binary information in twistor wire is complicated by the presence of demagnetizing fields resulting from the open flux path structure of the device. These fields modify the writing threshold of each bit and contribute an interaction with neighboring bits on the same wire. The effect of these demagnetizing fields has been measured with a search-coil technique. A simple procedure consisting of a coincident-current bit select followed by a single-current read select is used to form and "erase" the magnetized regions. It is found that the shape of the magnetized regions thus formed are a complex function of the two currents used and that the bits are not fully erased by the single current. The results suggest that demagnetization must be reduced by reducing thickness and/or bit density unless a more complex solenoid structure can be found to control the magnetization of the bit regions.

# BASIC SOLID STATE DEVICE CIRCUITS

## GENERAL

11,124 A REVIEW OF METHODS OF LINEAR NETWORK ANALYSIS IN THE STEADY STATE by P.W. Seymour (Austl. Natl. U.); Proc. IRE, Austl., Vol. 22, pp. 77-97, Feb. 1961

A thesis on methods of analysis of electric networks in the steady state is presented. Network response is characterized in terms of an independent set of network variables. Equilibrium equations are established for the loop current and node-pair voltage methods of analysis. Network transfer and response functions are derived. The admittance response functions for a linear passive n-mesh and the impedance response functions for a linear passive $(n+1)$ node network are described. Linear passive four-terminal networks are discussed and the full insertion loss expression derived. Image and iterative conditions are discussed. Fundamental formulae are derived to express the operating factor and input inverse reflection coefficients of a four-terminal network operating under non-

reference conditions in terms of the reference operating factor and various reference and nonreference inverse reflection coefficients.

11,125 NYQUIST DIAGRAM TRACER FOR A.F. by A.R. Bailey (A.M.I.E.E.); Electronic Tech., Vol. 38, pp. 156-159, May 1961

An instrument that enables the shape of the Nyquist diagram of a circuit to be determined in a very short time is described. The frequency range covered is from 20 cps to 5 kc, readings up to 20 kc being obtainable if suitable magnitude corrections are applied. The output may also be readily displayed as the resolved components of the signal under test by the use of two dc meters.

Micro-System Computers - See 11,197

11,126 TESTING MICROLOGIC ELEMENTS by R.H. Norman and R.C. Anderson (Fairchild); Proc. WJCC, Vol. 19, pp. 75-86, May 1961

The problem of testing micrologic elements, consisting of one to five DCTL NOR gates, whose components (resistors and planar transistors) are diffused into a single slab of silicon, is discussed. It is concluded that evaluation tests should be performed only on the terminals of such elements, and that it is more meaningful to evaluate the characteristics of the micrologic element which are functions of the internal component parameters (gain, leakage current, etc.) than the internal parameters themselves.

11,127 A COMPLETE TRANSISTOR EQUIVALENT CIRCUIT by R.H. Beeson (Fairchild); Proc. IRE, Vol. 49, pp. 825-826 (L), Apr. 1961

A complete junction transistor equivalent circuit is presented. The circuit is used to determine the voltage drop across a transistor chopper. The equations and equivalent circuits given by Ebers and Moll [Proc. IRE, Vol. 41, pp. 1761-1771, Dec. 1954] can be derived from the circuit. Together with these equations the circuit is valid in all three regions and in either the forward or reverse direction.

## AMPLIFIERS

Ultra-High Frequency Parametric Amplifier - See 11,146

Microwave Parametric Amplifiers - See 11,144 and 11,148

11,128 NARROW-BAND STABILITY LIMITED I.F. AMPLIFIER DESIGN by D. M. Duncan (Kreisler Australasia Pty. Ltd.); Proc. IRE, Austl., Vol. 22, p. 187 (A), Mar. 1961

A method of designing transistor IF amplifiers in order to obtain maximum power gain consistent with adequate stability was discussed. The design method covers the whole working frequency range of transistors. The method is generally applicable to any type of interstage coupling, however the following cases are considered in detail. (1) Narrow-band synchronously tuned single tuned transformers. (2) Narrow-band stagger tuned single tuned transformers. (3) Narrow-band inductively coupled double tuned transformers. The information needed to apply the design method is the transistor parameters and their range of variation under the proposed operating condition and the required parameters of the interstage coupling circuits. With this information the required input and output impedances of the coupling circuits and the optimum neutralisation (if used) can be readily calculated and with these parameters the design of the coupling circuits can be completed. The power gain of a stage is also derived in such a form that it clearly shows the effects of the following factors: (1) Stability requirements. (2) Operating point. (3) Neutralisation. (4) Operating frequency. (5) Actual values chosen for input and output impedance. (6) Type of interstage coupling network. Some notes are also included on transistor interchangeability and overload characteristics.

Linear Tunnel Diode Amplifiers - See 11,151

11,129 DIFFERENTIAL AMPLIFIER WITH REGULATOR ACHIEVES HIGH STABILITY, LOW DRIFT by R.D. Middlebrook (Calif. Inst. Tech.) and A.D. Taylor (Microdot); Electronics, Vol. 34, pp. 56-59, July 28, 1961

A circuit which consists basically of two differential amplifier stages followed by a single ended output is described. It exhibits several desirable characteristics usually unobtainable simultaneously in the common circuit configuration of a differential amplifier. The following figures are quoted as typical: gain stability ± 0.75 per cent; frequency response ± 1 per cent to 10 kc, 3 db down at 50 kc; differential input resistance greater than 1 MΩ; common-mode rejection factor 120 db to 400 cps, 100 db to 2 kc, for common-mode voltage ± 5 v peak and for a gain of 1,000. The gain is adjustable over a 2-to-1 range with a maximum preset to any value between 200 and 1,000. For a gain of 1,000 the maximum differential input signal is ± 5 mv peak. The output capability is ± 5 v into 20,000 Ω with output resistance less than 100 Ω, and with up to 100 per cent offset adjustment. The drift is to some extent a function of the signal source and a typical equivalent input drift is ± 100 μv for eight hours over a temperature range of 25° to 100°C. The same value of equivalent drift can be obtained over a temperature range of -55° to 100°C when the amplifier is used in conjunction with an internal heater.

Pulse Amplifiers - See 11,149

11,130 TRANSISTOR PULSE RESPONSE CIRCUIT by E. A. Hoskinson (NA Aviation); U.S. Pat. 2,981,850, Issued Apr. 25, 1961

A transistor pulse amplifier, of controlled output current and free from minoirty carrier storage effects, is described. A mono- or bi-stable multivibrator provides a low impedance path for the excess minority carriers in the base with a resultant improvement in rise time.

11,131 ZENER DIODE CREATES LOGARITHMIC PULSE AMPLIFIER by D. Ophir and U. Galil (Israel Inst. of Tech.);

Electronics, Vol. 34, pp. 68-70, July 14, 1961

A three decade logarithmic amplifier design using a Zener diode as the logarithmic device is presented. The behavior of the diode in a pulse circuit can be predicted from its dc characteristics. To obtain logarithmic behavior over three decades, a resistor is connected in series with the diode to straighten the curve in the upper region. Voltage amplification is obtained for pulses between 10 mv and 10 v. The amplifier also provides linear power amplification, transformation of the low impedance voltage source and output power amplification.

11,132 NOISE CONSIDERATIONS FOR HYBRID COUPLED NEGATIVE RESISTANCE AMPLIFIERS by J.C. Greene (Airborne Instr. Lab.); Proc. IRE, Vol. 49, pp. 626-627, Mar. 1961

The use of a hybrid network and two matched negative resistance amplifiers as an alternative to a system consisting of one negative resistance amplifier and a circulator, since the latter exhibits narrow band properties, is considered. The applicability of such a device to broad band amplification, however, is not considered generally practical since: (1) stringent requirements for well matched terminating impedances are imposed if stable operation is to be obtained with increased gain of the device, and (2) the signal source impedance has to be well matched if low-noise high-gain amplifiers are used and their noise performance is not to be significantly degraded by the presence of a conventional second stage. When the source is an antenna the mismatch will be considerable over moderately large frequency ranges or with antenna rotation.

11,133 PHASE SHIFTER. STUDY PROGRAM (NON-FERRITE) by K.E. Mortenson and C. Howell (Microwave Assoc.); U.S. Gov. Res. Rep., Vol. 36, p. 43 (A), July 5, 1961 AD 255 990

Two general phase-shifting techniques were investigated, both of which employ semiconductor elements. The first approach is the step or incremental phase-shifting device which provides for discrete changes in phase. The second phase-shifting approach is a continuously variable one which provides for a greater flexibility in phase control. Both the semiconductor material and the circuit problems involved in each of these two approaches were further explored in some detail. Results indicate that both the desired phase-shifting characteristics as well as power-handling capabilities can be reached.

11,134 VARIABLE CAPACITANCE DIODES USED AS PHASE SHIFT DEVICES by R.M. Searing (Lockheed); Proc. IRE, Vol. 49, pp. 640-641, Mar. 1961

An analysis on some previous results of the experimental use of variable capacitance diodes as phase-shift devices is presented. The model assumed for the analysis is a lossless transmission line terminated in a voltage tuned diode. Phase shift and loss are calculated for the abrupt diode function type where $C = C_0 (1 - v/\phi)^{-1/2}$. A phase shift of 180° is feasible because of the possibility of two changes of sign for certain restricted parameters. Experimental and calculated curves for the Hughes HPA-2800 at 1000 Mc are shown. Discrepancies are related to variations of the diode characteristics from the average values used for the calculations. Good agreement is found between the experimental and calculated values of attenuation. Maximum loss depends on the ratio of the series diode resistance to line impedance. A high $Z_0$ tends to reduce losses associated with phase shift of the diode.

11,135 TRANSISTOR AMPLIFIER by D.B. James (Bell Labs.); U.S. Pat. 2,994,832, Issued Aug. 1, 1961

A direct coupled push-pull transistor amplifier capable of accurate reproduction of extreme low level as well as high level signals is discussed. The amplifier is operated in class B for efficiency. The region of zero gain in the input-output characteristic common to class B operated transistor amplifiers is eliminated by employing a class A operated corrective stage to fill in the gap. This corrective stage comprises a difference amplifier driving a second pair of push-pull emitter followers connected in parallel with the principal output amplifier. The difference amplifier effectively amplifies the amount by which the output signal differs from the input signal thereby insuring an exact reproduction of the input signal at the load. The device may be employed as a direct coupled transistor amplifier in time division communication systems.

11,136 MISMATCHED INTERCONNECTION OF TRANSISTOR FEEDBACK AMPLIFIERS by E.M. Cherry (U. Melbourne); Proc. IRE, Vol. 49, p. 830 (L), Apr. 1961

The design of feedback transistor amplifiers is discussed. It is shown that the gain per stage of a cascade of series feedback amplifiers must be small if the gain is to be stabilized. The same can be shown in the case of a cascade of shunt feedback amplifiers. For the same uncertainty in gain an amplifier with more than twice the gain per stage of an amplifier in which similar stages are cascaded can be achieved by cascading alternate series and shunt feedback stages. Each stage operates under very nearly the ideal conditions for which its transmittance is stabilized. The interconnection method is particularly useful in the design of transistor video amplifiers.

11,137 DESIGNING CHOPPER-STABILIZED OPERATIONAL AMPLIFIERS by R.B. Fradella (United Electrodynamics); Electronics, Vol. 34, pp. 48-50, Mar. 3, 1961

Drift stabilization techniques in the design of chopper-stabilized operational transistor amplifiers are presented. A drift stabilized amplifier is presented in block diagram form and the design equations are developed. A practical circuit with a spot chopper is given and component values are determined by use of the design equations. A limiter circuit is also developed.

11,138 SIMULATING PARAMETRIC AMPLIFIERS by W.T. Hatley, Jr. (Rice Inst.); IRE Trans., Vol. ED-8, No. 2, pp. 116-123, Mar. 1961

Problems of producing a general simulator model of a parametric amplifier are discussed. This model is to be simple, accurate, and applicable to many forms of parametric amplifiers. A brief discussion of the theory behind parametric amplification is followed by proposals for three models. Each of these is discussed in terms of its limitations and applications. The results of tests on two of these models are presented, and these

results are discussed. Some emphasis is placed on the most successful of the models, which has been used to simulate a subharmonic oscillator.

11,139 WIDE BAND PARAMETRIC AMPLIFIER [in Japanese] by T. Okajima and H. Oshima (Elect. Commun. Lab. Tokyo); J. Inst. Elect. Commun. Engrs. Japan, Vol. 44, p. 8, Mar. 1961

The application of a negative susceptance perturbation circuit in the design of a wide band, single diode parametric amplifier is discussed. An equivalent circuit is derived, which indicates a bandwidth considerably greater than that of corresponding amplifiers with single resonators is possible. However, the difference between the signal and idling frequency should be small. Experimental results of the parametric amplifier operating at 6000 Mc are presented. A bandwidth of 170 Mc and a gain of 15 db were obtained in double sideband reception.

11,140 THEORY OF NONRECIPROCAL AMPLIFIERS WITH EQUAL INPUT AND OUTPUT FREQUENCIES USING NONLINEAR SEMICONDUCTOR ELEMENTS [in German] by R. Maurer and K.-H. Löcherer (Telefunken, Ulm); Arch. Elekt. Uebertragung, Vol. 15, pp. 71-83, Feb. 1961

The four-pole equations and the transducer gain are derived for nonreciprocal amplifiers, consisting of cascaded tunnel diode up- and down-converters or cascaded parametric diode up- and down-converters. If the tunnel or parametric diodes are fed with pump voltages of different phases, decoupling between output and input can be achieved by means of an additional linear, passive and reciprocal coupling admittance. For mixed devices containing one tunnel diode and one parametric diode such decoupling between output and input is possible even for pump voltages of equal or opposite phases. In the noninverting case power matching at the input and output is always possible. If two tunnel diodes or one tunnel diode and one parametric diode are used, the numerical transducer gain in the forward direction can exceed unity if the pump power is properly chosen. With two parametric diodes the device operates as an isolator. In the inverting case the value of the numerical transducer gain can always be made to exceed unity, but simultaneous power matching at input and output is then possible only with the use of two tunnel diodes.

11,141 SOLID STATE AMPLIFIER by K.M. Poole and P. K. Tien (Bell Labs.); U.S. Pat. 2,970,274, Issued Jan. 31, 1961

A parametric amplifier which utilizes a rod consisting of alternate layers of a ferrimagnetic material such as yttrium iron garnet (YIG) and a diamagnetic material such as sapphire as the active element is described. The active element, with a helix resonant at the signal frequency wrapped around it, is placed in a cavity resonant at the pump frequency at a point of high magnetic flux. The rod and concentric helix are placed in a hollow quartz support post about which is wound another helix conductor (in the direction opposite to that of the inner helix). A dc magnetic field is applied to the rod at an angle of 45° to both the axis of the signal helix and the magnetic field associated with the pumping power. The laminations of the rod are at an angle of 45° to the axis of the signal helix so that the applied magnetic field is perpendicular to the YIG layers. The arrangement concentrates the signal flux along the axis of the helical resonator. High power gains result since it is possible to achieve high filling factors with an inductive element of small volume.

11,142 PARAMETRIC AMPLIFIERS by G.S. Stracca (Marelli-Lenkurt); Alta Frequenza, Vol. 30, pp. 244-254, Mar. 1961

Low noise varactor diode amplifiers are described. A theoretical comparison is made of gain, bandwidth, noise and stability of both the negative resistance amplifier and upper or lower sideband converters. The discussion is limited to simple tuned circuits for the sake of simplicity. The diode losses play an important part, limiting the frequency range within which any one type of diode can be employed. It is brought out that the characteristics of all different types of amplifiers can be represented in terms of a diode's characteristic frequency in a very general and representative manner. Some experimental results are also reported.

11,143 A WIDE BAND SINGLE DIODE PARAMETRIC AMPLIFIER USING FILTER TECHNIQUES by A.G. Little (Stanford Electronics Lab.); U.S. Gov. Res. Rep., Vol. 36, p. S-39 (A), July 5, 1961 PB 154 369

A single diode parametric amplifier, using filter techniques to achieve a broad bandwidth, is described. The amplifier has a 200 Mc bandwidth at 3.3 kMc, with a gain of $16\frac{1}{2}$ db and a noise figure of 1.8 db. The amplifier is used in the Stanford Radio Spectroheliograph to provide improved sensitivity for the study of cosmic radio signals.

11,144 A NONDEGENERATE S-BAND PARAMETRIC AMPLIFIER WITH WIDE BANDWIDTH by G. Shaffner and F. Voorhaar (Motorola); Proc. IRE, Vol. 49, pp. 824-825 (L), Apr. 1961

A single diode S-band parametric amplifier which operates in the nondegenerate mode is described. Bandwidths up to 80 Mc have been measured at a center frequency of 2.5 kMc, with voltage gain-bandwidth products of 500 Mc and noise figures of 2.0 db. This gain-bandwidth product is the highest yet reported for a single diode nondegenerate S-band parametric amplifier. Wide bandwidths were attained by utilizing broadband filters in the signal and idler circuits. The amplifier can be operated in the following modes: (1) wide band with the idler termination at room temperature, (2) wide band with cooled idler termination for lower noise figures, (3) narrow band without the external idler termination for minimum noise figure, and (4) regenerative up-converter with X-band output.

11,145 STAGGERED OPERATION OF DOUBLY RESONANT PARAMETRIC AMPLIFIERS by S. Hamada and H. Mukai (Nippon Tel. and Tel.); Rev. Elect. Commun. Lab. NTT, Vol. 9, pp. 22-25, Jan.-Feb. 1961

A study of the staggered operation of doubly-resonant variable-capacitance parametric amplifiers in the 6 Gc band, in order to obtain a broad bandwidth, is discussed. A double-resonant amplifier has been achieved by inserting a resonant stub into a waveguide cavity. The experimental results, especially the improvement of bandwidth characteristics by adjusting the phase difference between the pumps of two parametric amplifiers connected in cascade, are reported. For a gain of 29 db, a bandwidth of 55 Mc has been obtained.

11,146 A UHF-RANGE VARIABLE-CAPACITANCE STRAIGHT-THROUGH AMPLIFIER [in German] by K. Bomhardt (Telefunken, Ulm); Arch. Elekt. Uebertragung, Vol. 15, pp. 153-160, Mar. 1961

## AMPLIFIERS (Cont'd)

A laboratory model of a tunable variable-capacitance diode straight-through amplifier is described. It operates over a tuning range of 480 to 750 Mc. The bandwidth and the noise figure of the amplifier are investigated. There are two possibilities for tuning over a wide range of frequencies, i.e., tuning of the signal frequency and the pump frequency in the same sense with a fixed idle frequency, or in opposite senses with a fixed pump frequency. It is shown that tuning in opposite senses offers more advantage. Results of measurements on the laboratory setup are presented and shown to be in good agreement with theory. With a bandwidth of 10 Mc an improvement of the noise figure is obtained by a factor of 4.5 to 2.2 over the noise figure of a conventional triode amplifier in a grounded-grid configuration.

11,147 EFFECT OF HIGHER HARMONIC COMPONENTS ON THE PERFORMANCE OF THE TRAVELING-WAVE PARAMETRIC AMPLIFIER by S. Saito (U. Tokyo); Proc. IRE, Vol. 49, pp. 623-624, Mar. 1961

The transformation of the mode coupling equations for the parametrically excited uniform transmission line to the well known mode coupling equations for the ordinary transmission line by introducing the concept of the apparent propagation constants is developed. The following assumptions are made: (1) Small signal theory can be applied, (2) the pumping wave is large enough compared with the signal and its harmonics, but sufficiently small for neglecting second order coupling between signal and pumping waves, (3) all the propagating modes carry positive power, and (4) the continuously coupled transmission line is lossless. The determination of the propagation constant enables evaluation of the normalized amplitudes and thence calculation of the amplification and the noise figure of a traveling wave parametric amplifier. The effect of higher harmonic components on amplification and noise figure may also be calculated.

11,148 THE HELIX PARAMETRIC AMPLIFIER – A BROADBAND SOLID-STATE MICROWAVE AMPLIFIER by C.L. Cuccia and K.K.N. Chang (RCA); RCA Rev., Vol. 22, pp. 219-244, June 1961

A parametric amplifier which uses a helix as a slow-wave distributed interaction structure and has variable-capacitance solid-state diodes distributively coupled to the helix is described. An applied signal and a pump signal are coupled to the input of the helix; interaction occurs with the diodes and provides parametric amplification of the applied signal at the output of the helix. The helix parametric amplifier has an insertion loss of approximately 30 db between the input and the output of the helix before application of the pump signal; net gains as high as 38 db have been measured with the pump signal applied. Experimental operation of helix parametric amplifiers in the 2200 to 2300 Mc and 1800 to 2000 Mc frequency bands is described. Gains in excess of 30 db have been measured over narrow frequency ranges. Operating bandwidths from 5 to 10 per cent at substantial gain have been achieved at pump frequencies less than twice signal frequency. Terminal signal-sideband noise figures as low as 4.5 db have been measured.

11,149 THE DESIGN OF DISTRIBUTED AMPLIFIERS USING SILICON DOUBLE-DIFFUSED TRANSISTORS by P.J. Beneteau and L. Blaser (Fairchild); Solid State J., Vol. 2, pp. 38-43, Mar. 1961

A simplified procedure for designing compensated and uncompensated distributed amplifiers using silicon mesa transistors is described. Distribution amplifiers permit the optimization of the gain-bandwidth product at large values of output current. Experimental models exhibited a gain of 20 db up to 200 mc with compensation and 20 db up to 175 mc without compensation. Amplifiers of this type find application in very fast pulse amplifiers and in RF test equipment.

Tunnel Diode Amplifiers - See 11,074

11,150 TUNNEL DIODE APPLICATIONS by C.D. Todd (Hughes); Elect. Engrg., Vol. 80, pp. 265-271, Apr. 1961

Some circuit applications of tunnel diodes are discussed. Tunnel diode amplifiers, oscillators, pulse circuits, r-f converters, and harmonic generators are covered. Circuit combinations of tunnel diodes and transistors are also discussed. These include bistable memory elements which utilize the desirable features of both devices, circuits with n-type negative resistance characteristics, and the use of transistors to increase or decrease the operating current level of tunnel diodes.

11,151 GAIN VS BANDWIDTH LIMITS FOR ESAKI DIODE AMPLIFIERS by J.S. Logan; Proc. IRE, Vol. 49, p. 832 (L), Apr. 1961

Expressions for the theoretical limits on gain vs bandwidth for Esaki diode linear amplifiers in three different configurations are presented. Transmission type amplifiers, reflection type amplifiers, and reflection type amplifiers with circulators are considered.

Transistor Power Amplifier - See 11,191

## OSCILLATORS

11,152 STABILIZED TRANSISTOR OSCILLATOR by R. A. Hilbourne (Hazeltine Res.); U.S. Pat. 2,980,865, Issued Apr. 18, 1961

An oscillator in which the sinusoidal wave form and frequency are stabilized against transistor parameter variations is described. The circuit utilizes two transistors and a bimorph crystal which closes the high Q regenerative loop. Saturation is prevented by connecting a diode biased just below the value at which saturation would occur. Second harmonic components of 0.2 to 0.3 per cent were observed at 1,000 cycles. Frequency stability was found to be essentially dependent on the frequency-temperature characteristics of the crystal.

11,153 A TRANSISTORIZED FREQUENCY SYNTHESIZER by G. Husson and B.N. Sherman (Canadian Marconi); J. Brit. IRE, Vol. 21, pp. 347-350, Apr. 1961

A synthesizer which provides 30,000 discrete frequencies between 2 - 32 Mc in steps of 1 kc with the stability of the driving frequency standard is discussed. The phase-locked loop principle is used. A variable frequency oscillator covers the 2 - 32 Mc range and, for each desired frequency, a suitable arrangement of frequency conversion and filtering allows the oscillator to lock on a fixed frequency directly derived from the standard. Spurious signals and noise generated respectively by mixers and harmonic generators, are greatly attenuated since the phase-locked loop acts as an "active filter." In particular the "catching range" of an automatic phase control

loop is examined and a method for greatly increasing this catching range by very simple and economical means is described.

11,154 VOLTAGE CONTROLLED OSCILLATOR by C.D. Rausch (Savage Ind.); U.S. Pat. 2,980,864, Issued Apr. 18, 1961

An oscillator in which the frequency is linearly related to the input signal is described. A diode is coupled in a forward conducting mode to a tuned circuit. The impedance of the diode, which is varying approximately as the square of the current through it, compensates for the square root relationship of the capacitance to the frequency of the tuned circuits, thus achieving a linear variation of frequency with signal voltage. The device can be operated under extreme environmental conditions and is suited for telemetry.

11,155 TRANSISTOR OSCILLATOR by L.H. Dülberger (Fischer and Porter); U.S. Pat. 2,970,280, Issued Jan. 31, 1961

A transistor oscillator which provides a low harmonic output is described. The output frequency is variable from 4 cps to 100 kc by changing capacitors in a bridged-T feedback network. Direct coupled transistors are used with bias voltages obtained through diodes. Positive feedback is provided at all frequencies with a minimum negative feedback existing at the notch of the characteristic of the bridged-T so that oscillations are stabilized at this notch frequency. Direct current feedback is used to stabilize the transistors.

11,156 A TRANSISTOR MULTIVIBRATOR by B. Rakovich (Faculty of Elect. Engrg., Belgrade); Elect. Engrg., Vol. 33, pp. 303-305, May 1961

An emitter-coupled free-running multivibrator is described. The durations of quasi-stable states are controlled by the charging and discharging of one timing capacitor. This circuit provides a suitable means of generating symmetrical and unsymmetrical rectangular waveforms with short transitions from one stable state to another. Another useful feature is that this circuit can generate rectangular pulses of fairly good shape at very low frequencies.

11,157 TRANSISTOR MULTIVIBRATOR by E.N. Armanini (NA Aviation); U.S. Pat. 2,976,427, Issued Mar. 21, 1961

A continuously variable linear time base and gate generator is described. A monostable multivibrator circuit uses negative feedback to provide a triangular wave output from one transistor and a square wave output from the other. Normal multivibrator action switches a positive going potential to the base of the cutoff transistor. A feedback path couples a negative going potential to the base to oppose the positive going potential resulting in a modified effect on the base which produces a triangular output at the collector. The length of time that the transistor can be held conducting is determined by the base bias. Using an emitter follower between the collector and the charging capacitor increases the duty cycle to over 90 per cent.

11,158 STABLE-FAST RECOVERY TRANSISTORIZED MULTIVIBRATOR CIRCUIT by W. A. Geckle, Jr. (U.S. Army); U.S. Pat. 2,976,432, Issued Mar. 21, 1961

A stable transistor multivibrator capable of unsymmetrical operation (95 per cent duty cycle) is described. The output pulse is of uniform width regardless of circuit loading. The multi-vibrator transistors are connected through a diode and the emitter-collector path of additional transistors to B+. A timing capacitor connected through diodes provides a low impedance path to turn off the second transistor when the first conducts. When the transistor cuts off, the additional transistor is forward biased to charge the coupling capacitor and supply current to the base of the first transistor resulting in a fast rise time. The additional transistors supply a low impedance charge and discharge path for the coupling capacitor to increase the rise times.

11,159 PULSE WIDTH CONTROL FOR MULTIVIBRATORS by G. L. Haugen and G. D. Wofford (Bendix); U.S. Pat. 2,975,300, Issued Mar. 14, 1961

A method for controlling the pulse output duration of a group of multivibrators without interaction is described. A control transistor is connected in the collector circuit of the first stage with the bases of all control transistors connected together. The control transistor emitter potential will approximate the control voltage on its base, presenting a different voltage to the charging capacitor to change the pulse duration. There is no interaction between the controlled multivibrators since voltage changes at the control transistor emitter do not affect its base voltage. The control transistor can be used in the collector of the first stage or the base of the second stage.

11,160 HIGH POWER TWO-TERMINAL NEGATIVE RESISTANCE OSCILLATOR by R. Scarlett and R. Henley (Shockley); U.S. Gov. Res. Rep., Vol. 36, p. S-37 (A), July 5, 1961 PB 154 400

A theoretical investigation of the performance of four-layer diodes as generators of RF power is described. It is intended to calculate ultimate frequency and power limitations, and to determine the device design requirements for obtaining maximum performance. The results are presented of calculations intended to determine the power and frequency capabilities of 4-layer diodes operating as RF power oscillators in a Class C mode. The important features of this mode of operation are described, and an efficient push-pull oscillator circuit shown. From the requirements on the diode parameters for proper operation, the power output and power dissipation are calculated and plotted as a function of frequency. The factors which limit performance and the selection of parameters for maximum efficiency are discussed. Finally, some preliminary experiments verifying the qualitative behavior of the diodes are reported.

Tunnel Diode Oscillators - See 11,074, 11,151

11,161 EMITTER FOLLOWER TRANSISTOR OSCILLATOR by C. E. Lowe (Genl. Motors); U.S. Pat. 2,972,226, Issued Feb. 14, 1961

A switch consisting of an emitter follower transistor oscillator with parallel resonant base and emitter circuits is described. When the resonant frequency of the base resonant circuit is higher than that of the emitter resonant circuit, oscillations are generated and a large current flows from a battery in the collector circuit. When the resonant frequency of the base circuit is equal to or lower than that of the emitter circuit, no oscillations are generated and the current flow from the battery is very low. The resonant frequency of the base resonant circuit is changed by moving a core in the field of an

## OSCILLATORS (Cont'd)

inductance in the resonant circuit. The oscillator is particularly suited for control applications which require sensitive power control at high speed in response to minute mechanical movements.

11,162 THE DYNAMICS OF A SUBHARMONIC OSCILLATOR WITH LINEAR DISSIPATION by G. J. Lasher (IBM Res. Ctr.); IBM J. Res. and Dev., Vol. 5, No. 2, pp. 157-161, Apr. 1961

A mathematical analysis of the dynamic behavior of subharmonic oscillators (parametrons) is made assuming a nonlinear reactance but a linear dissipation or resistance. Simple equations of motion for the subharmonic and pump amplitudes are derived in the quasistatic, or high-Q, approximation. Numerical solutions are obtained for two cases. The first shows the subharmonic amplitude changing from a small value to its steady state value when a constant pump signal is applied. The second shows decay when the pump signal is removed.

## SWITCHING CIRCUITS

11,163 SYNTHESIS OF THRESHOLD LOGIC COMBINATORIAL NETWORKS by L. Dadda (Electronic and Polytechnic Inst., Milan); Alta Frequenza, Vol. 30, pp. 224-231, March 1961

The problem of synthesizing arbitrarily assigned switching functions using only threshold element is considered. Elementary threshold functions, i.e., functions that can be implemented by a single threshold circuit, are first characterized for 2, 3, and 4 variable cases. Two methods are then illustrated for the synthesis of nonelementary functions, and the results for the primitive functions of the symmetry classes of 2 and 3 variables are given.

Basic Switching Circuits for Broadcasting Systems - See 11,189

Design and Performance of Electronic Switching Systems - See 11,192

Tunnel Diode Bistable Circuits - See 11,200

Flip-Flop Circuit Employing an RCL Loaded Film Device - See 11,204

11,164 THE JUNCTION TRANSISTOR IN FLIP-FLOP CIRCUITS [in Czech.] by V. Spany; Slaboproudy Obzor, Vol. 22, pp. 231-239, Apr. 1961

A survey of flip-flop circuits utilizing two junction transistors of the same or complementary conductivity type is presented. The circuits described constitute either an improvement on conventional techniques or a new departure in circuit engineering. Some circuits which have not previously been described in the literature are included.

11,165 BISTABLE FLIP-FLOP CIRCUIT WITH MEMORY by D. F. Hilbiber (Lockheed); U.S. Pat. 2,982,870, Issued May 2, 1961

A bistable flip-flop capable of returning to its last state in the event of temporary power failure is described. The flip-flop transistors have their emitters grounded through a common silicon diode with cross coupling provided by pairs of series connected silicon diodes. A capacitor connected to the junction of each pair of coupling diodes charges to a polarity dependent upon which transistor is conducting. If power loss occurs, the capacitor discharges rapidly through the conducting transistor until the capacitor voltage is too low to overcome the potential barrier of the silicon diodes. This voltage remains on the capacitor for a period of time determined by the leakage current through the diodes. When power is restored, the capacitor voltage is sufficient to cause the transistor which was saturated prior to power loss to return to saturation. A one μfd mylar capacitor resulted in a memory time of 20 minutes.

11,166 TRANSISTOR BISTABLE CIRCUITS by E. H. Cooke-Yarborough (Atomic Energy Authority, London); U.S. Pat. 2,994,002, Issued July 25, 1961

A junction transistor bistable circuit using complementary transistors is described. A diode connected between the collectors controls the switching point. For an increase diode current, the diode voltage drop offsets the drop in the rest of the circuit, providing a low output impedance. When the diode current decreases, the diode impedance rises and the output impedance becomes large and negative, switching the circuit. Resistors from the collector of one transistor to the base of the other prevent the accumulation of minority carriers in the base. The circuit can be triggered by pulses to the emitter or base of either transistor.

11,167 TRANSISTORIZED CORE FLIP-FLOP by E.G. Clark (Burroughs Corp.); U.S. Pat. 2,994, 788, Issued Aug. 1, 1961

A complementary flip-flop with conditional steering means is described. The conditional steering means represents the ideal means for preventing time race in a complementary flip-flop since the length of the delay between the change of state of the flip-flop and the reversal of the steering gates is determined by the width of each complementing input pulse; therefore the flip-flop will operate with complementing input pulses of indefinite duration. The schematics of the complementary flip-flop employing magnetic cores and embodying the use of conditional steering are included with the detailed description of its operation.

11,168 PHANTASTRON CIRCUITS USING TRANSISTORS by N. C. Hekimian (Def. Dept.); Electronics, Vol. 34, pp. 46-47, Feb. 24, 1961

A three transistor circuit with characteristics equivalent to a vacuum-tube phantastron circuit is described. Three different methods are presented. Two transistors, with the collector of one feeding the emitter of the other, are connected across a divided load resistor of a third transistor. The collector current divides between the load resistor and the emitter-collector path of the parallel transistors. Another method achieves the two distinct regions by introducing transistor saturation. The change in operation is also obtained by using a p-n-p transistor as a commom-emitter amplifier and an n-p-n transistor as a common-collector amplifier. The two transistors conduct at different collector voltage levels of a third transistor.

Monostable Multivibrator Gate Generator - See 11,157

11,169 TRANSISTOR GATE CIRCUITS by D. E. Deuitch (RCA); U.S. Pat. 2,995,664, Issued Aug. 8, 1961

Transistor gating circuits which operate with low level input

signals and which have a degree of memory to allow for non-coincidence of input pulses are described. An input pulse is applied through a series resistor to the collector of a junction transistor with the output taken across the emitter and collector. An inhibit gate is produced by applying a control signal to the base to saturate the transistor. The resulting low impedance sharply attenuates the output signal. An AND gate is produced by biasing the transistor into saturation and cutting it off with a control pulse to the base when an input signal is applied to the collector. Another application is the memory effect produced by carrier storage in the base which provides an output pulse when input pulses are noncoincident. The degree of memory is controlled by the value of reverse bias applied.

11,170 VARIABLE LEVEL GATING CIRCUIT by N.L. Wiseman and C.W. Baxter (Genl. Dynamics); U.S. Pat. 2,986,655, Issued May 30, 1961

A gating circuit which produces an output pulse when two or more signals derived from the same signal source are applied to it is described. The peak-to-peak input signal potential, $E_i$, of the signal source is applied to the base of the gating transistor. Simultaneously the average dc potential component of the input signal, $E_c$, derived from an RC averaging circuit, is applied, by means of an emitter follower circuit, to the emitter of the gating transistor. When $E_i$ is more positive than $E_c$, the n-p-n gating transistor conducts and produces negative-going pulses. Square waves can be formed by chopping these output waves.

11,171 BLOCKING OSCILLATOR CONTROLLED TWO-TRANSISTOR BILATERAL SWITCH by G.L. Richards (Genl. Dynamics); U.S. Pat. 2,976,431, Issued Mar. 21, 1961

A bilateral switch which can pass a signal voltage larger than the control voltage is described. A controlled blocking oscillator, using a storage effect transistor to increase the duty ratio, produces a train of pulses as long as its control transistor is held on. The oscillator output is rectified and fed through a constant current filter to a pair of switching transistors which control the flow of load current. The filter consists of a choke and a diode. The high duty-ratio of the blocking oscillator and the flywheel effect of the filter choke supply a steady current to the switching transistors when the blocking oscillator is on. Since the controlling circuit is isolated from the controlled circuit, a small control voltage can switch a large signal voltage.

Tunnel Diode Switches - See 11,074

Transistorized Switch - See 11,161

11,172 TWO-STATE APPARATUS by N. F. Moody (Min. Natl. Def., Canada); U.S. Pat. 2,980,805, Issued Apr. 18, 1961

A two-state circuit in which a reduction in resolving time is achieved by controlled saturation, while employing a minimum of components and power supplies, is described. The circuit is based on the observation that the limiting value of storage carriers is set by the base current. The value of the charge and the time required to remove it are little dependent on transistor saturation. A pair of complementary transistors is used in which the collector of each transistor is connected to the base of the other thus forming a p-n-p-n or n-p-n-p unit. The circuit is applicable in the field of fast digital techniques.

## SIGNAL CONVERTERS

11,173 A FAST TRANSISTORIZED DISCRIMINATOR by H. Verweij (CERN); Nuc. Instr. Methods, Vol. 10, pp. 308-314, Apr. 1961

A fast transistorized discriminator in which the threshold can be varied from 100 mv to 2.1 v is described. Stable operation is obtained for rates up to at least 10 Mc. The unit gives a negative output pulse of 2.5 - 3 v and a positive output pulse of 9 v, both into 125 ohms.

11,174 DIFFERENTIATOR AND MIXER CIRCUIT by G. L. Clapper (IBM); U.S. Pat. 2,975,303, Issued Mar. 14, 1961

A signal differentiating and mixing circuit is described. Individual inputs are connected through input capacitors to the emitter of a p-n-p transistor with a diode connected between the base and emitter. The collector is direct-coupled to an n-p-n emitter follower with both transistors biased off. A capacitive feedback path is provided from the emitter follower to the input transistor emitter. A positive pulse at any input triggers the input transistor. The voltage swing at the emitter is limited to the saturation voltage of the emitter-base diode providing isolation of the inputs. Pulse shaping is accomplished by feedback. A noise rejection threshold is obtained by biasing the emitter follower well beyond cutoff. The direct application of the input capacitor displacement current to the emitter with no significant swing in emitter voltage results in true differentiation.

11,175 TUNNEL DIODE DOWN CONVERTERS by D. G. Peterson (Lockheed); Proc. IRE, Vol. 49, pp. 1225-1226 (L), July 1961

Noise figures associated with tunnel diode down converters are discussed. The diode is represented by a two-port model bridged by a shot-noise generator. The noise figures are developed and compared with those developed by Chang and Breitzer. The difference in the noise-figure expression derived by Breitzer and that derived by Chang is analyzed. It is concluded that Breitzer has derived the more exact noise-figure expression.

## WAVE GENERATORS

Sine Wave Generator - See 11,152

11,176 GENERATION OF NANOSECOND CARRIER PULSES AT X-BAND WITH TUNNEL-DIODES by L.U. Kibler (Bell Labs.); Proc. IRE, Vol. 49, p. 1204 (L), July 1961

The use of a gallium antimonide point-contact tunnel-diode to generate RF pulses with a carrier frequency of 11 Gc is described. An unencapsulated diode is mounted directly across a 0.015 x 0.9 inch X-band waveguide and formed after assembly into the waveguide. A 10 Mc switching pulse is applied to the diode. Since the waveguide acts as a high-pass or differentiating circuit, the diode is switched on the rising and falling edges of the driving pulse to generate RF pulses. The separation between the pulses depends on the time that the driving pulse amplitude exceeds the valley voltage.

## WAVE GENERATORS (Cont'd)

Sweep Generators for Color TV Receivers - See 11,190

11,177 PULSE GENERATOR by K. G. MacLean and B. A. Trevor (RCA); U.S. Pat. 2,981,852, Issued Apr. 25, 1961

A circuit for generating short pulses from a sinusoidal input voltage is described. The pulse recurrence frequency is equal to the frequency of the input voltage source. The sine wave output of a stable frequency source is differentiated and applied to the base of a switching-type transistor which is biased to conduct in response to a negative voltage applied to its base. When the transistor is driven into conduction, the resultant change of voltage at the collector saturates a saturable reactor coupled to the collector. When the transistor reverts to its original nonconducting state, the reactor is saturated in such a direction that a negative voltage pulse is developed. This negative pulse is applied to a second switching-type transistor to drive the latter into conduction. The pulse appearing at the collector of the second transistor is differentiated and fed into a suitable output circuit for utilization. Pulses with half amplitude widths on the order of 0.02 μs have been produced. The device has particular application in a frequency control or frequency stabilization system using pulse locking techniques.

## PULSE CIRCUITS

11,178 PULSE DELAY CIRCUIT by N. C. DeTroye (Philips); U.S. Pat. 2,975,302, Issued Mar. 14, 1961

A pulse delay circuit based on the diffusion time-constant in transistors which provides accurate delay times of 10-60 μsec is described. The base and emitter of a grounded-base transistor are connected across a transformer secondary which supplies positive pulses of 2 μsec duration. The collector is supplied through a series resistor with long pulses of opposite polarity. A differentiating circuit is connected to the collector. At the end of the positive control pulse, the transistor remains conducting because of accumulation of charge carriers in its base. The collector voltage starts to decrease after the free charge carriers drain off. The leading and trailing edges of the collector voltage pulse are differentiated and the positive pulse suppressed. A delayed negative pulse is produced by each positive control pulse with a delay time dependent upon the diffusion time constant of the transistor and the collector resistance.

## RECTIFYING CIRCUITS

11,179 SILICON RECTIFIER DESIGN TECHNIQUES by Dr. R. Lynch (Westinghouse); Electronic Ind., pp. 98-102, Mar. 1961

A summary of design problems and suggested techniques for series or parallel operation of silicon rectifiers is presented. Three methods of series operation are described: use of resistive voltage dividers, capacitive voltage dividers, and special designs. Matching reverse characteristics is not recommended. Parallel operation techniques described are: matching of the forward characteristics, addition of resistance or reactance in series with each cell, and use of balancing transformers or separate transformer windings. Equations for maximum power dissipation are developed.

11,180 UNIDIRECTIONAL SIGNAL TRANSLATING DEVICE by H. M. Straube (Bell Labs.); U.S. Pat. 2,975,301, Issued Mar. 14, 1961

A rectifying circuit with improved signal sensitivity and forward-to-reverse current characteristics is described. The emitter-base junction of a transistor is used to rectify the input signal with an amplified output from the collector direct-coupled to a second transistor of opposite conductivity type. The second stage is direct-coupled to an emitter follower whose emitter-collector circuit is in shunt through the power supply with the input transistor rectifying junction. A forward going signal at the input encounters the conductance of the emitter-base path shunted by the high conductance of the emitter follower emitter-collector path. A high impedance path is presented to reverse polarity signals. Response to low level signals is increased by a factor of 30 over a single transistor while the forward-to-reverse current ratio is increased by a factor of 2000.

11,181 DESIGN OF CONTROL REACTOR OF SEMICONDUCTOR RECTIFIER [in Czech.] by Z. Kresaddo; Elektrotech. Obzor, Vol. 50, pp. 156-161, Mar. 1961

The calculation of the core-set dimensions of a control reactor designed both for the operation of a semiconductor rectifier with fixed current control and for the power control of the same is discussed. In designing the reactor for fixed power control, not only the dc voltage regulation but also the volt-ampere characteristics of the load and the size of the commutating circuit must be taken into account. The rating of the reactor also depends, in general, on the value of the commutating voltage. The inner diameter of the toroidal core is also given by the dc current rating of the rectifier, by its scheme, by the space factor of the core window as well as by the specific current density and the cooling system of the main winding of the control reactor.

## OTHER BASIC CIRCUITS

Rectifying Semiconductor Circuits - See 11,210

11,182 CONSTANT OUTPUT IMPEDANCE NETWORK by J. M. Wier (Bell Labs.); U.S. Pat. 2,981,851, Issued Apr. 25, 1961

A two-state transistor circuit of constant output impedance which couples a signal from a variable output impedance source to a fixed load, thereby minimizing power loss and signal reflections, is described. The fidelity of the circuit for transmitting data information was established with the help of a high-speed data transmission system and a time bias detector.

Limiter Circuits - See 11,188

11,183 A NOTE ON SIGNAL-TO-NOISE RATIO IN BAND-PASS LIMITERS by C. R. Cahn (Space Tech. Labs.); IRE Trans., Vol. IT-7, pp. 39-43, Jan. 1961

A simplified analysis is presented to explain physically the change of signal-to-interference ratio which occurs in a band-pass limiter. The analysis utilizes the concept of sideband resolution into symmetric and anti-symmetric parts and considers only the asymptotic case where the signal-to-interference ratio is small in comparison with unity. Wideband correlation-detection systems are discussed, as well as ordinary band-pass systems. The important conclusion is reached that the

degradation is highly dependent on the statistics of the interference amplitude fluctuations. However, when the signal is weak compared to the interference, the maximum possible degradation is 6 db and occurs for constant-amplitude interference. Degradation with noise interference in a wideband correlation-detection system has been obtained for arbitrary signal and noise bandwidths. It is found that the degradation ranges between 0.6 and 1.0 db, the latter figure being for the case where the signal bandwidth is greater than approximately three times the noise bandwidth.

11,184 CORRECTED DIODE by D. L. Ort (Litton Systems); U.S. Pat. 2,980,806, Issued Apr. 18, 1961

A clamping circuit of good voltage regulating properties and low transient voltage variations is described. One half of a transistor is utilized as a "corrected" diode in which a substantial amount of any current flowing through it is cancelled by a reverse current flowing through the other half of the transistor, the latter half being reverse biased. Voltage variations of 0.05 to 0.23 v are achieved for a current range of 5 μa to 5 ma, using a 2N27 transistor. This value is about half as much as in a circuit using the same type of transistor without reverse biasing.

# APPLICATIONS OF SOLID STATE DEVICES

## MEDICAL

11,185 AN ELECTRIC THERMOMETER FOR MEASUREMENT OF THE SKIN TEMPERATURE by V. V. Tret'yakov and P. A. Ondzul (Riga Res. Inst. Traumatology and Orthopedics); Bull. Exp. Biology and Medicine, Vol. 51, pp. 245-246, Feb. 1961

An instrument which utilizes the temperature dependence of current in a point contact diode to measure skin temperature in the temperature range 30° - 40°C is described. The diode is used as one arm of a bridge and the temperature is read from an indicator graduated between 30° and 40°C. The instrument has a thermal inertia of 10 - 15 seconds and an accuracy of ±0.1°C.

11,186 ELECTRONIC OBSTACLE AND CURB DETECTOR FOR THE BLIND by J. M. Benjamin, Jr. (Biophysical Electronics); 1961 IRE Int. Conv. Rec., Vol. 9, Part 9, pp. 135-140

An obstacle detector, with a range of 2 - 8 ft and a laboratory model curb detector, ranging from 3 - 7 ft are described. Both instruments range by optical triangulation using pulsed light in the near infrared and germanium photodetector. Output from a gated amplifier trips a multivibrator which operates a tactile stimulator in the handle. The curb detector detects holes, down-steps and up-steps either by means of the high rate of change when the beam traverses a curb, or by momentary light loss on approaching a curb. The general design requirements of such instruments are discussed.



11,187 THE APPLICATION OF ALLOY DIFFUSED TRANSISTORS TO THE DOMESTIC BROADCAST RECEIVER by J. R. Goldthrop (Mullard-Austl.); Proc. IRE, Austl., Vol. 22, p. 188 (A); Mar. 1961

The performance requirements of the domestic broadcast receiver relative to the transmission standards and the subjective assessment of the end user were discussed. An indication of running costs against designed maximum audio power output enables the designer to select the most suitable battery for a "cordless" receiver, while it was shown that the desired HF gain may be obtained with a self-oscillating mixer and a single 455 kc IF stage if suitable alloy diffused transistors are selected for the task. The design parameters of resonant ferrite antennae were examined and optimized for efficient matching to the mixer input circuit. The amplified AGC system proposed for the illustrative design gives a 46 db control range. A sensitivity of 200 μv/meter is achieved with a complement of five transistors and two germanium diodes.

11,188 SEMICONDUCTOR LOW-LEVEL LIMITER by W. F. Chow (GE); U.S. Pat. 2,982,866, Issued May 2, 1961

Full wave limiters in which the output is limited to about 25 mv constant for raw FM inputs of over 1.1 v are described. Variation of the ac collector impedance as a function of small bias changes provides the basis for the limiting action. Two pairs of transistors with parallel base and emitter connections are used. The impedance modulation in alternate half cycles of the two parallel paths limits the positive and negative swing of the input signal. The low level limiting simplifies the circuitry necessary for removal of noise in FM receivers since amplification of the raw FM signal is obviated.

11,189 APPLICATION OF TRANSISTORS TO BROADCAST PROGRAMME SWITCHING by B. R. Perkins (Postmaster-Genl's Dept., Austl.); Proc. IRE, Austl., Vol. 22, pp. 325-331, May 1961

An electronic switching circuit which overcomes contact resistance difficulties that are found in keys, relays, or uniselectors is described. An analysis is made of the basic switching circuit, to determine the most suitable operating conditions and this basic circuit is then modified to suit the particular requirements of program switching. A description of associated control equipment is given and one method of constructing an electronic switching system is suggested. The results of tests on a prototype system indicate that the proposed circuit satisfactorily meets the required standards of performance.

11,190 CHROMA-SWEEP GENERATOR USING SILICON VARIODES [in Japanese] by T. Kitao and H. Fukuhara (Matsushita Elect. Ind.); Natl. Tech. Rep., Vol. 7, pp. 28-35, Mar. 1961

A sweep signal generator for adjusting chroma circuits in color television receivers is discussed. Four silicon variodes (voltage sensitive semiconductor capacitors) are used as frequency varying elements. By making a beat frequency from two sweep oscillators, which sweep opposite to each other against the variation of a sweep voltage, an excellent quality of linearity of output sweep frequency is achieved. The advantages over the usual variable μ method lie in the possibility of smaller sizes since no exciting cores are used, and there is less power consumption and negligibly small frequency drift due to variations such as temperature, linearity, and line voltage.

## TELEPHONY AND TELEGRAPHY

11,191 TRANSISTOR TONE GENERATOR AND POWER AMPLIFIER by G. F. Cerofolini (Auto. Elect. Labs); U.S. Pat. 2,994,833, Issued Aug. 1, 1961

A transistor tone generator and power amplifier capable of operating with good efficiency from a relatively high voltage dc power source is described. The power amplifier consists of two or more transistors transformer-coupled to a load. The transistors are connected in series for direct current and the bias adjusted for each one so that they divide the total voltage equally. The transistors are effectively operated in parallel for ac signals so each supplies its own signal power to the associated primary winding of the output transformer. Each transistor supplies substantially the same amount of output power and the input driving power for each is inversely proportional to the dynamic current gain factor. A schematic diagram and discussion is given on a ringback tone generator for a telephone system. The circuit comprises a 400 cps generator, a synchronism shaper, a 40 cps multivibrator, a modulator and an output power amplifier. The device is useful for producing a modulated tone such as is required in a telephone exchange.

11,192 AN ELECTRONICALLY CONTROLLED PAX — ITS DESIGN AND PERFORMANCE by S. Yamato, K. Watanabe, K. Muroga, and J. Okuda [in Japanese] (Nippon Elect.); Abst. J. Inst. Elect. Commun. Engrs. Japan, Vol. 44, p. 10, Feb. 1961

The design, operating experience, and performance data of a 200-line semi-electronic switching system in use continuously since March 1960 are discussed. The system employs miniaturized wire-spring crossbar switches as the speech path, and diodes and transistors as the control. Each speech path consists of two wires for the speech, one wire for holding the crosspoint, and one wire for memorizing the using link. Diodes are utilized for logic performance, while transistors are used for amplification, memory, and timing. This system is expected to provide long term practical data on semiconductor reliability, as well as information applicable to the future development of electronic switching systems.

11,193 TRANSISTORIZED REPEATERS FOR A 120-CHANNEL CARRIER TELEPHONE SYSTEM by J. F. Lansu (Philips); Philips Telecommun. Rev., Vol. 22, pp. 105-107, May 1961

The main characteristics of a completely new repeater equipment design for a 120-channel system on balanced carrier cables, which satisfy the CCITT recommendations for a circuit length of 2500 km, are discussed. Field testing has been completed and the equipment is now in production.

11,194 THE IRISH TELEGRAPH NETWORK EQUIPPED WITH TRANSISTORIZED VF EQUIPMENT by H. Bouwman (Philips); Philips Telecommun. Rev., Vol. 22, pp. 173-178, July 1961

The transistorized voice frequency equipments installed in the Irish telegraph network are described. One type is an amplitude modulated system in "conclave" construction which comprises 18 channels in the 420-2460 cps band. Another comprises 6 channels in the 1140-1740 cps band. A third is a speech + duplex system where the speech band is limited to 700 cps, and a choice of 4 telegraph frequencies is available; i.e., 2820, 2940, 3060, and 3180 cps. When the telegraph channels of the third system extend over two or more telephone links in tandem, by-pass circuits are employed.

11,195 A LOW-NOISE MICROPHONE PREAMPLIFIER by A. B. Bereskin (U. Cincinnati); 1961 IRE Int. Conv. Rec., Vol. 9, Part 2, p. 22 (A)

A low-noise two-transistor preamplifier which has been developed for use with microphones is described. For a source resistance of 1000 ohms, a noise figure of 1.3 db has been achieved. A corresponding middle frequency gain of 40 db, bandwidth of 30 kc and output impedance of 175 ohms is achieved.

## COMPUTERS

11,196 DESIGN OF AN ALL-MAGNETIC COMPUTING SYSTEM. Part I. CIRCUIT DESIGN by H.D. Crane and E. K. Van De Riet (Stanford Res. Inst.); IRE Trans., Vol. EC-10, pp. 207-220, June 1961

The circuits used in a decimal arithmetic unit which utilizes ferrite magnetic elements and copper conductors only are described. The arithmetic operations of addition, subtraction, and multiplication are performed with a product and sum capacity of three decimal digits. The sole logical building block of this system is a two-input inclusive-OR module with a fan-out capability of three with any desired positive and negative combination. The system involves the use of some 325 modules, each of which contains two magnetic multi-aperature devices (MAD's). The circuit and physical arrangement of the machine are described in detail. The system is controlled from a manual keyboard, and readout from the machine is via incandescent lamps controlled directly from the MAD elements with no intermediate elements being required. The "worst cast" drive-pulse amplitude range for the completed machine, varying all clock pulses simultaneously, is ±10 per cent.

11,197 MICRO-SYSTEM COMPUTER TECHNIQUES by E. Luedicke and A. H. Medwin (RCA); Proc. WJCC, Vol. 19, pp. 95-109, May 1961

Some of the problems of building very high-speed (nanosecond) computer systems are described. A number of techniques for building tunnel diode computers are discussed, and it is emphasized that the difficulties are due to the operating frequency, rather than to any characteristic of the switching device. Among the items which are discussed are: ceramic circuit wafers with fired-on metallized circuitry and ground plane, vacuum deposited rod resistors, grooved channel wiring assemblies which hold the wafers, a new approach to a flexible transmission line, and a tunnel diode memory plane.

Design of Logic Networks - See 11,163

Switching Circuits - See 11,172

11,198 LOGIC COMBINES TUNNEL DIODES WITH TRANSISTORS by R. W. Lade (Marquette U.); Electronics, Vol. 34, pp. 46-47, Mar. 3, 1961

Tunnel diode-transistor logic circuits which have a 0.7 nsec switching rate, permitting computer operation at a clock rate of 500 Mc, are described. A transistor in the common emitter configuration contains a tunnel diode in the emitter lead. The input characteristic consists of the series connection of a forward biased pn junction and the normal tunnel diode characteristic. When the circuit is driven by a constant current

source, the tunnel diode speed is independent of transistor performance. The combination provides the fast switching time of the tunnel diode and the isolation capability of the transistor.

11,199 DIGITAL SYSTEM OF MECHANICALLY AND ELECTRICALLY COMPATIBLE BUILDING BLOCKS by D. F. Parkhill, D. C. Redpath, and T. C. Ross (Avco Mfg.); U.S. Pat. 2,976,428, Issued Mar. 21, 1961

A system of compatible plug-in units to build up equipment for performing logical decisions in computers, data-handling systems and automatic control systems is described. When the Boolean equations and block diagrams of the required system are set up, the association of the units is immediately indicated. The system uses five basic units: a bistable trigger, a complementary amplifier, an AND gate, a multiple OR gate, and a gated amplifier. The units are compatible with each other. The maximum PRF is 1 Mc and the temperature range is -50° to +85°C.

Switching Characteristics of Semiconductor Devices - See 11,092

Testing of Micrologic Elements - See 11,126

Semiconductor Switches for Magnetic Core Memory Systems - See 11,071

11,200 100-MC TUNNEL-DIODE RING COUNTER by F. P. Heiman (RCA); Proc. IRE, Vol. 49, p. 1215 (L), July 1961

A tunnel-diode ring counter which operates successfully using a 100 Mc sine wave input is described. Bistable tunnel-diode AND circuits are ring connected with a delay between each stage. The input to each stage is a short transient from the input line and a dc input from the preceeding AND stage. When a stage is triggered, a reset pulse is applied to the preceeding stage. The delay between successive stages is obtained from the finite switching time of each tunnel-diode. The transient input is obtained by differentiating the output from a tunnel-diode when the input voltage exceeds a predetermined level.

11,201 AN AUTOMATIC SELF-CHECKING TRANSISTOR COUNTER WITH DIGITAL DISPLAY by H. I. Messer and W. H. P. Leslie (Natl. Engrg. Lab.); Electronic Engrg., Vol. 33, pp. 484-490, Aug. 1961

An automatic self-checking transistor counter with digital display and provision for a digital readout is described. The automatic checks are carried out before the desired count is made and test the accuracy of the counting circuits, gating circuits, central frequency standard and the display system. Plug-in units are used throughout to simplify fault-finding and maintenance. The device was developed for use in the laboratory or in data-logging systems.

11,202 CHARACTER RECOGNITION AND PHOTOMEMORY STORAGE DEVICES FEASIBILITY STUDY by D.M. Baumann, F. T. Brown et al. (MIT); U.S. Gov. Res. Rep., Vol. 35, p. 807 (A), June 16, 1961 PB 147 787

A study to determine the feasibility of high speed photoelectric scanning of printed material is reported. The desired goal is to develop a system that will scan and encode printed matter in a fashion suitable for digital computer input. Photoelectric character recognition, related optics, and photomemory development are discussed. A theory of weighted area scanning is presented which yields a voltage by means of a photocell.

11,203 THIN MAGNETIC FILM MEMORIES FOR HIGH-SPEED COMPUTERS by E. E. Bittmann (Burroughs); Electronics, Vol. 34, pp. 39-41, Mar. 3, 1961

Reproducible thin film memories with cycle-time capabilities of 0.2 μsec are described. Planar 80-20 NiFe films, approximately 2000 angstroms thick, are vacuum deposited on glass substrates under a 10-50 oersted magnetic field. The films show a preferred direction magnetization, with all domains parallel to the direction of the applied field. The film exhibits a square hysteresis loop in the preferred direction but has a linear loop when magnetized perpendicular to the easy direction. The film remagnetizes predominantly by a spin-rotational mechanism rather than domain wall movement. To reduce transistor dissipation, the film is read out during the rise time of the word drive pulse and written into during the fall time. An interconnected stack of 16 memory planes is capable of storing 320 eight-bit words.

11,204 MAGNETIC FILM DEVICES USING PASSIVE LOADING by J. M. Daughton, T. A. Smay, A. V. Pohm, and A. A. Read (Iowa State U.); J. Appl. Phys., Suppl. to Vol. 32, pp. 36S-37S, Mar. 1961

The use of magnetic film devices as storage and logical elements in digital computers is evaluated. Solutions of equations based on the Landau-Lifshitz model indicate that, with passive loading, such an application is feasible. Experimental models of a flip-flop consisting of an R-C-L loaded film device indicate that successive 20 oe, 0.1-μsec drive field pulses can switch the magnetization in the film alternately from one rest orientation to the other, with repetition rates of the drive on the order of $10^6$ cps. A nondestructive readout memory element consisting of an R-L loaded thin film device is shown. Films with $H_k$ on the order of 3 oe can be driven in the hard direction by 15 oe, 0.05-μsec field pulses without destroying the stored information, resulting in output voltages of about 25 mv per winding turn. Fabrication by evaporation techniques of a memory employing such elements is discussed.

11,205 MAGNETIC CORES, CHARACTERISTICS AND APPLICATIONS by R. Stuart-Williams (Ampex Computer); Auto. Control, Vol. 15, pp. 37-43, July 1961

A general description of magnetic-core storage units is presented. The units are divided into general purpose and special purpose classes and information relative to both classes is given. A detailed description of the operation of a buffer storage unit and a typical random-access storage unit is presented. The operation of a typical small buffer storage unit is explained and a description of some special features utilized in buffer storage units is given.

Twistor Storage Devices - See 11,123

11,206 COMPOUND CRYOSARS FOR LOW-TEMPERATURE COMPUTER MEMORIES by R. H. Rediker and A. L. McWhorter (Lincoln Lab.); Solid-State Electronics, Vol. 2, pp. 100-105, Mar. 1961

The characteristics and applications of compound cryosars are discussed. The compound cryosar operates at the liquid-helium temperature. It consists of two regions of compensated germanium, one more heavily doped than the other, in series between

## COMPUTERS (Cont'd)

two ohmic contacts. When the more lightly-doped region is broken down by impact ionization of the impurities, the impurity conductance of the more heavily-doped region limits the current. This current limiting, in addition to the negative-resistance of the breakdown, permits use of a matrix array of compound cryosars in a coincident-voltage memory. If desired, the impact ionization breakdown of the more heavily doped region may be used for a nondestructive readout. High density arrays of compound cryosars can be operated in a high-speed (10-100 Mc) computer memory, with a power dissipation for 200,000 elements of less than 0.25 w.

11,207 DIFFERENTIATION AND INTEGRATION WITH THE AID OF TRANSISTORS [in Czech] by V. Spany (Higher Tech. School, Kosice CSR); Elektrotech. Cas., Vol. 12, No. 2, pp. 99-110, 1961

Differentiation and integration with the aid of junction transistors is described. New circuits are discussed and a simplified but sufficient analysis is presented. The use of feedback is not advantageous for the differentiation and integration process; on the contrary, in the case of integration the feedback is undesirable.

11,208 FULL BINARY ADDER WITH ONE TUNNEL DIODE by B. Rabinovici and C. A. Renton (RCA); Proc. IRE, Vol. 49, pp. 1213-1214 (L), July 1961

Full binary addition using a single tunnel diode and three resistors in a Wheatstone bridge network is described. The SUM and CARRY outputs are obtained through the bridge balancing action when input voltages are applied. The SUM output, with two inputs, is 10-20 times below that for one or three inputs. With one input, the bridge is balanced and no CARRY output is obtained. With two or three inputs, an unbalance exists and a CARRY output voltage is obtained. The transient response in the SUM and CARRY outputs is no greater than 10 μsec. The CARRY output is above ground, but a transformer has been used to convert it to a single-ended output. The circuit has the advantages of simplicity, potential high-speed operation, no steady-state dissipation and low switching energy.

11,209 HIGH SPEED A/D CONVERSION WITH SEMICONDUCTORS by R. C. Platzek, H. F. Lewis, and J. J. Mielke (Autonetics); Auto. Control, Vol. 15, pp. 37-41, Aug. 1961

A high speed, semiconductor, bipolar analog voltage encoder, accepting and continuously converting voltages which are static or varying at a rate not exceeding 2500 v per sec is described. The operating principles of the reversible counter, error detector, clock generator and digital-to-analog decoder are discussed in detail.

## POWER

11,210 METHODS AND FUNDAMENTAL RESULTS OF THE INVESTIGATION OF SEMICONDUCTOR RECTIFIERS CONTROLLED BY SATURABLE REACTORS [in Czech] by J. G. Golstov; Elektrotech. Obzor, Vol. 50, No. 5, pp. 250-253, 1961

The analysis of a rectifier device consisting of dry rectifiers and saturable reactors connected in series for a three-phase arrangement is given. Unlike a single phase arrangement, the ascertainment of the relations of the effective or the mean values of the loading current is not sufficient and the shape of the current curve must also be known. The objective of this work is the determination of the best arrangement of the rectifier installation with regard to both material savings, efficiency and simplicity of regulation.

11,211 REGULATED INVERTER by N. B. Buck (Sunstrand); U.S. Pat. 2,987,681, Issued June 6, 1961

The conversion of direct current into alternating current by an inverter employing two transistors and a feedback transformer is described. Unbalanced leaking currents in the two transistors cause one of them to conduct and the other to cut off, while the saturation of the core of the feedback transformer will reverse this order of events. The output frequency of the alternating current is directly proportional to the voltage across the feedback transformer. This voltage can be stabilized by connecting across the feedback winding a full-wave rectifier which has a dc voltage regulator connected across its output terminals. Different circuits for the dc voltage regulator are included.

## CONTROL

11,212 TRANSISTOR MAGNETIC INVERTER FOR SPEED CONTROL OF AC MOTORS by N. Ilynski (U. California); U.S. Gov. Res. Rep., Vol. 35, p. 724 (A), June 1961
PB 150 792

The design and operation of a power transistorized inverter supplying a single-phase reluctance motor is reported. Transistorized power inverters were successfully used in many cases because of their high efficiency, small sizes, lack of moving parts, and reliability. Different inverter circuits were studied; the inverter was designed and built. The main characteristics of the inverter with different kinds of load (resistive, inductive) were obtained. The influence of the inverter parameters on its characteristics was investigated. Characteristics of the reluctance motor were obtained when it was supplied from a sine voltage source and from the inverter.

11,213 THE TRANSISTOR AS A TEMPERATURE-SENSING DEVICE IN TEMPERATURE CONTROL SYSTEMS by J. E. Pallett (U. London); Electronic Engrg., Vol. 33, pp. 360-363, June 1961

The method of using a transistor, in the common-base circuit, for the detection of temperature changes in a temperature controlled system is examined in some detail. It is shown that it has two main advantages over methods; the sensitivity may be as high as IV per °C and the output current is directly proportional to temperature. It is, of course, limited to temperatures below 90°C for germanium transistors or below 150°C for silicon transistors.

## INSTRUMENTATION

11,214 AN AC SILICON RESISTIVITY METER by C. C. Allen and W. R. Runyan (Texas Instr.); Rev. Sci. Instr., Vol. 32,

pp. 824-828, July 1961

A versatile, all transistor silicon 4-point probe resistivity meter incorporating a dc probe bias supply in conjunction with an ac measuring circuit is described. It is direct reading and covers a resistivity range of 0.01 - 300 ohm-cm full scale. With minor changes the range can be increased to 1000 ohm-cm.

11,215 VOLTAGE COMPARATOR by L. M. Germain (Burroughs); U.S. Pat. 2,987,629, Issued June 6, 1961

A maximum potential indicator, for identifying the maximum potential from a plurality of different potentials, consisting of transistor stages with base terminals coupled together, is described. The potentials to be identified are fed into the emitter terminals of the transistors. When interrrogated, the transistor having the most positive potential at its emitter terminal conducts first and will cut the other transistors off. A minimum potential indicator for identifying the minimum potential from a plurality of different potentials is built based on a similar idea.

11,216 PORTABLE ELECTROMETER VOLTMETER by W.E.K. Gibbs (Austl. Def. Sci. Service); J. Sci. Instr., Vol. 37, p. 296, Aug. 1960

A portable, high impedance dc voltmeter for measuring voltages up to 2 v and impedances of up to $10^{10}$ ohms is described. The accuracy attained is about 2 per cent of full scale deflection and the short term zero drift is also of this order. The hybrid circuit uses an electrometer input followed by transistor amplifier stages.

11,217 CHARACTERISTICS OF P-I-N JUNCTION DETECTORS by J. W. Mayer, H. L. Dunlap (Hughes Aircraft), and H. E. Wegner (Los Alamos Sci. Lab.); Bull. Am. Phys. Soc., Ser. II, Vol. 6, p. 313 (A), Apr. 24, 1961

The characteristics of lithium-drifted p-i-n junction charged-particle detectors were discussed. The detectors were constructed from p-type base material of 12 to 1400 ohm-cm resistivity following the technique of Pell, and have active volumes between 1 and 4 mm thick. The change in junction capacitance as a function of time indicates that lithium precipitation occurs, is present in all resistivities in the heavily doped front region, and results in increased depletion depths. Precipitation in the drifted region produces a decrease in the sensitive volume and was observed in all material with resistivities less than 1000 ohm-cm. The precipitation time constant increases with increasing resistivity. A combination dE/dx and E gas ion chamber and p-i-n junction detector system was used to observe protons, deuterons, and tritons from $C^{12}$ and $Be^{9}$ bombarded with 17-Mev $He^{3}$ ions. Electron response from 50 to 2000 kev was studied with a beta-ray spectrometer. Typical energy resolutions were 1 per cent and 4 per cent for 17-Mev deuterons and 1800-kev electrons, respectively.

11,218 RESISTANCE STRIP MAGNETIC ELECTRON MULTIPLIER by G. W. Goodrich and W. C. Wiley (Bendix); Rev. Sci. Instr., Vol. 32, pp. 846-849, July 1961

A magnetic electron multiplier which utilizes a strip of semiconductor material rather than a conventional multi-element dynode structure is described. Especially suitable for use in demountable vacuum systems, it amplifies and detects the electrons which result from bombardment of the cathode with ions, neutral molecules, photons, etc. Gains over $10^{7}$ and dark currents lower than 0.1 electron per second referring to the cathode, have been obtained. The addition of crossed field gates to rapidly direct the output beam to any one of several output anodes is discussed. Theory of operation and results of experimental measurements are reported.

11,219 MAGNETIC-INDUCTION METERS EMPLOYING THE HALL EFFECT (Air Info. Div.); U.S. Gov. Res. Rep., Vol. 36, p. 133 (A), July 5, 1961 AD 255 785

A measuring device, called a gaussmeter, was developed for direct measurement of magnetic induction. It can be used more conveniently than conventional fluxmeters, since there is no need to move the sensor in and out of the magnetic field during measurements. Another of its advantages, in comparison with conventional fluxmeters, is the small size of the sensor with the halotron (4 x 2 x 0.2 mm), which permits accurate, almost point-to-point field measurements. These measurements can be applied not only to the values but also to the distribution of magnetic fields in narrow gaps of electromagnets or electric machines, as well as to dissipation fields. Gaussmeters of this type can be built for measuring magnetic induction in constant and variable magnetic fields with frequencies up to 10 to the 12th power cps. Gaussmeters used for measuring magnetic induction in constant fields are discussed.

11,220 INVESTIGATION OF HALL EFFECT DEVICES FOR FLAW DETECTION IN FERROUS MATERIALS by J. Rossnick (Frankford Arsenal); U.S. Gov. Res. Rep., Vol. 36, p. 133 (A), July 5, 1961 AD 255 890

An investigation of the state of the art in the development of Hall generators as applied to nondestructive testing has shown that the field of activity in both basic and applied work is limited but increasing very rapidly. Two magnetometer instruments are commercially available which can be used for the detection of magnetic leakage fields caused by cracked ferromagnetic materials. The limitations of various methods in crack detection are discussed with emphasis on the need for an effective flaw depth measurement technique. Experimental procedures and test results are described for various modes of operation such as dc, ac, and pulse power control current with a discussion of sensitivity, resolution and stability factors.

11,221 THE APPLICATION OF SUPERCONDUCTIVITY TO THE DETECTION OF RADIANT ENERGY by D. H. Martin and D. Bloor (U. London); Cryogenics, Vol. 1, pp. 159-165, Mar. 1961

The construction and operation of a radiation detector which utilizes the loss of resistance suffered by a superconducting metal on cooling through its transition are described. The minimum detectable signal of the detector is less than $10^{-12}$ w for a receiving area of 3 mm x 2 mm and an overall time constant of 1.25 sec. Response is uniform over the spectrum from the visible and near infrared to wavelengths exceeding 1 mm. The gain in signal-to-noise ratio over the best thermal detectors operating at room temperature is about 100. The theory and operation of the detector, including an analysis of the noise figure of the electrical circuit (parts of which are at 4°K), is given.

11,222 THERMOCOUPLE THERMOMETRY by R. L. Powell and L. P. Caywood, Jr. (Natl. Bu. Stand.); Prog. Cryogenic Engrg. Conf., p. 38 (A), Aug. 1961

A report on the calibration of three thermocouples is given: alumel vs chromel (ISA type KN-KP); constantan vs iron (ISA

type JN-JP); and constantan vs iron (ISA type YN-YP). In addition to the actual detailed calibration tables, there is a quantitative discussion of the thermoelectric inhomogeneities caused by variations between different lots of wire. Fixed point calibrations are also given for a commercial thermocouple, gold-palladium vs platinum-irridium, and a specially prepared alloy system of silver-gold vs copper. None of the commercial thermocouple systems prove to be as useful at low temperatures as either gold-cobalt or constantan vs copper.

11,223 ON THE USE OF A RADIOACTIVE SOURCE IN THE VELOCITY MEASURING SENSING HEAD ON A SLED ON THE HIGH-SPEED TRACK by H. E. Carr (Alabama Polytech. Inst.), and H. G. Hanson (U. Minnesota); U.S. Gov. Res. Rep., Vol. 35, p. 581 (A), May 16, 1961 PB 153 826

Various radioactive sources and means of signal detection are considered for use in the volocity measuring sensing head now used in the space-time system at the Holloman track. Numerous advantages and limitations of such sources and detectors are considered. The most attractive possibility is the use of a 1 Curie gamma ray source in the 0.1 to 0.3 Mev range. To obtain a detector which is suitably rugged yet sensitive, modest development costs will be required. To date the best choice is a solid state photodetector with a luminescent crystal. Other detectors are too delicate or otherwise insufficiently developed at this time. A new method of space-time determination is proposed for use once the radioactive source technique is practicable.

11,224 STRAIN MEASUREMENTS AT CRYOGENIC TEMPERATURES by P. T. Chiarito (NASA); Prog. Cryogenic Engrg. Conf., p. 39 (A), Aug. 1961

Alloys used in conventional high-temperature as well as room-temperature strain gages and the mounting technique are evaluated for use between 20°K and room temperature. Measured strains were well into the plastic region. On the basis of stability and small apparent strain per °K, the best results were obtained with a combination of stabilized Armour alloy and a 2-mil thickness of GA-5 epoxy cement. A device is described for measuring the strain sensitivity factor throughout the temperature range.

11,225 THE USE OF A THERMISTOR FOR DETECTING EFFLUENT FRONTS IN LIQUID-SOLID CHROMATOGRAPHY by G. S. Ross (Natl. Bu. Stand.); J. Res. Natl. Bu. Stand., Vol. 65C, pp. 245-247, Oct.-Dec. 1961

A thermistor used to detect temperature changes corresponding to the arrival of separated constituents in liquid-solid chromatography is described. The thermistor cell is an integral part of the column. The temperature of the outside of the column is held constant, either by a controlled water bath or by a metal cell containing a heating coil controlled electronically by a separate thermistor and transistor amplifier. Temperature changes within the column vary from 0.1°K to a few degrees. A plot of thermistor data and simultaneously taken optical refractive index data is shown as a check for the method.

11,226 PULSE SHAPE DISCRIMINATION IN STILBENE SCINTILLATORS by W. Daehnick and R. Sherr (Princeton U.); Rev. Sci. Instr., Vol. 32, pp. 666-670, June 1961

A simple, sensitive pulse shape discriminator which was designed to permit detection of low energy neutrons in the presence of a very high γ-ray background, and at high counting rates is described. An improvement relative to discrimination circuits available is obtained by incorporating a fast crystal diode switch for the separation of the fast and slow parts of the scintillator de-excitation pulse. This device greatly reduces interference effects of nearly coincident detector pulses and also permits better pulse matching and comparison. The best discrimination is obtained for moderate sensitivity and counting rates, where out of $10^5$ detected γ-rays about one was erroneously admitted. A detailed description of the circuit and accessories is given, and results of test runs at 20 Mev FM cyclotron are presented.

11,227 ELECTRONIC TIMING DEVICE by C. W. Skelton and J. S. Mason (Texas Instr.); U.S. Pat. 2,970,226, Issued Jan. 31, 1961

An electronic timer which will accurately actuate an output device is described. A crystal oscillator, kept at a constant temperature by a heater in an insulated oven, provides the basic timing frequency. Binary counting chains are employed to register the time intervals. One form of the invention is an intervalometer which produces successive pulses at regularly spaced intervals. Another form of the invention is a miniature timer which produces an output after a preselected period of time up to days.

## OTHER APPLICATIONS

11,228 CIRCUIT BREAKER WITH SEMICONDUCTOR DIODES [in Czech] by V. Husa, J. Kriz, and J. Ladnar (State Res. Inst. Elect. Engrg., Bechovice); Elektrotech. Obzor, Vol. 50, No. 9, pp. 480-482, 1961

A new method of circuit-breaking by means of semiconductor diodes is described. The principle was verified by tests and the physical conditions for the rectifying parts, suitable for a circuit-breaker with semiconductor elements, were investigated.

11,229 A MAGNETIC JOURNAL BEARING by F. T. Backers (Philips); Philips Tech. Rev., Vol. 22, pp. 232-238, 1960/61

The substitution of magnetic bearings for conventional bearings, to eliminate wear and friction between them and a rotating shaft, is described. The shaft floats in the field produced by the magnetic bearings, which consist of ring magnets fixed upon the shaft situated within a set of outer stationary ring magnets. The rings consist of ferroxdure I and are radially magnetized. The magnetization is alternately directed towards and away from the shaft, and opposing inner and outer rings have mutually opposed directions of magnetization. A theoretical condition for optimum dimensioning has been derived and confirmed by experiments. The bearing is stable in the radial direction; in the axial direction it is stabilized by a simple electromechanical servo-system.

# NEW PRODUCTS

## MATERIALS AND DEVICES
(including Test and Fabricating Equipment)

11,230 CONTROLLED RECTIFIERS (Westinghouse Electric Corp., Semiconductor Dept., Youngstown, Pa.)

A series (2N 681) of medium power controlled-rectifiers (Trinistors) is announced. Analogous to a thyratron in conduction characteristics, the device, in its reverse direction, exhibits the very low leakage characteristic of a silicon rectifier. In the forward or conducting direction, conduction is initiated by a signal pulse to the control terminal or "gate." The device then switches rapidly to a conducting state with very low voltage drop and high current-carrying capabilities. If a gate signal is not applied, the device will not conduct below a rated forward blocking voltage. Features of this series include: forward current 16 amperes half-wave (25 a dc); transient reverse voltages to 400 v; forward blocking voltages to 300 v; and high surge current ratings.

11,231 EPITAXIAL MESA TRANSISTORS (Philco Corp., Lansdale Div., Lansdale, Pa.)

Silicon diffused epitaxial MESA transistors combining high voltage and power ratings with low storage time and saturation voltage are announced. The new 2N2086 and 2N2087 transistors feature very high gain bandwidth product ($F_t$) permitting design of circuits with switching rates greater than 15 Mc at currents as high as 300 ma. The devices are specifically designed for use as large memory plane core drivers, high current line drivers, and high voltage pulse-amplifiers for data-processing equipment.

11,232 TRANSISTOR HEAT DISSIPATORS AND RETAINERS (International Electronic Research Corp., 133 West Magnolia Blvd., Burbank, Calif.)

Heat dissipating and retaining devices (Series TXB) for mounting all model TO-18 (0.170" to 0.190" diameter) and model TO-8 (0.480" to 0.510" diameter) JEDEC outline transistors are announced. Acting as an efficient thermal link between transistor and heat sink, these devices have demonstrated ability to retain transistors in a vibration environment of 10 to 2000 cps at 15 G per MIL-STD-202, Method 204, Condition B, and to withstand shock per MIL-STD-202, Method 202 at 100 G. They are also salt-spray resistant. Made of beryllium copper, they are available in various combinations of hardware and finish.

11,233 PHOTOCELLS (Solid State Products, Inc., One Pingree St., Salem, Mass.)

A series of diffused junction p-n-p-n semiconductor photocells (Photrans) is announced. They are capable of bistable operation and will directly handle pulses to 5 amperes from a single optional light or electrical triggering input. Their p-n-p-n latching features, large power handling ability, and high speed recommend them for use in counting, sorting, power control, programming, precision indexing, and optical logic control

11,234 COAXIAL DUPLEXER (Microwave Associates, Inc., Burlington, Mass.)

A rugged, compact, lightweight, all-solid-state coaxial duplexer (MA-3477) is announced for applications at L-band which require 5 to 10 per cent bandwidth in the 1000-14000 Mc region. It has a low insertion loss (1.0 db maximum) and a recovery time of under 10 milliseconds. Transmitter-receiver isolation at rated power regardless of antenna mismatch is 40 db (minimum). It will handle 1.5 kw peak power (at a 0.001 duty cycle) and up to 60 watts CW. Input VSWR at any arm, high and low level, is 1.3 (maximum). Temperature operating range is -55° to +85°C.

11,235 INDUSTRIAL BATCH OVENS (Blue M Electric Co., 138th and Chatham St., Blue Island, Illinois)

A series of industrial batch ovens in two temperature ranges and in six standard sizes from 16 to 96 cubic feet are announced. Featuring positive mechanical convection and horizontal airflow, the ovens heat to 356°F (180°C) and 600°F (316°C). A dual-scale calibrated thermostat provides quick reading and setting of oven temperature. All models are of heavy steel construction with fiber-glass wool insulation and enamelled exterior. They may be used for general aging, curing, drying, baking, and similar operations.

11,236 DIODE THERMAL RESISTANCE TESTER (Wallson Associates, Inc., Dept. PR, 912 Westfield Ave., Elizabeth, N.J.)

A thermal resistance tester (Model 222) that accurately measures the junction temperature of semiconductor diodes and rectifiers is announced. Working on a null circuit principle, the instrument is designed so that a rise in junction temperature may be read directly from a front panel meter in degrees centigrade. An adaptor to permit thermal resistance measurements of transistors also will be available.

11,237 MINIATURE PARTS HANDLER (Mini-Tool Industries, Box 84, Highbridge Station, New York 52, N.Y.)

A parts-handling system using vacuum suction to move and manipulate tiny, delicate components quickly and easily is announced. Developed for the semiconductor and miniaturization fields, the device consists of a slim, fingertip-controlled suction pencil coupled with an adjustable vacuum source. The device is inexpensive and operates at regular line voltages.

11,238 WHISKER ATTACHER (Kulicke and Soffa Mfg. Co., Inc., 401 North Broad St., Philadelphia 8, Pa.)

A machine (Model 415) for attaching whiskers to alloy junction transistors is announced. Combining automation of some operations with simplified manual micropositioning, features of the machine include: 17-header, pre-load magazines; automatic header indexing; exact length wire-feed; and unit control of spotweld and cutoff tools. All operations are observed through an optionally provided stereo microscope.

## UNITS AND SYSTEMS

11,239 PORTABLE TV BROADCAST UNIT (Shibaura Electric Co., Tokyo, Japan)

A highly mobile, completely transistorized television broadcasting unit much smaller, of less than half the weight of similar units, and capable of operation with two-thirds less power consumption is announced. The entire unit is mounted on a small, 60 hp bus chassis, and includes two video cameras; synchronizing pulse generator; video switching, mixing, and monitoring equipment; and microwave relay transmitter.

11,240 THREE CHANNEL COUNTER-TIMER (Transistor Specialties Inc., Terminal Dr., Plainview, N.Y.)

Model 365 RP, a transistorized, remotely-programmable, 10 Mc counter-timer is announced. The unit operates in nine different modes and is capable of complete measurement performance in the time-frequency domain. All measurements are performed directly and accuracy is ± count ± the stability of the oven-stabilized crystal time base (± 5 parts in $10^8$ per week); resolution is 0.1 μ sec, sensitivity is 50 mv, and input impedance is 1 megohm shunted by 40 pf.

11,241 BIDIRECTIONAL COUNTER (Crane Co., Hydro-Aire Div., 300 Winona Blvd., Burbank, Calif.)

A fully transistorized bidirectional counter which indicates true position while going through zero in either direction is announced. The counter can be preset or reset to any reference number and can be optionally provided to reset automatically after each operation. A memory storage of essentially unlimited duration insures accuracy despite irregular or interrupted input information. The instrument has a counting rate of 45,000 counts per second and reads out to 5 standard decades and a polarity indicator.

11,242 POWER SUPPLY (Power Sources, Inc., Burlington, Mass.)

An all silicon device power supply (Model PS4241 M) operational in ambient air of 71°C, is announced. Convection cooling is employed, eliminating blowers or moving parts. Dc output is 245 - 255 v at 0 - 200 ma with ac input of 105 - 125 v, 60 - 63 cps (400 cps optional). Line regulation is less than 0.05% change in output voltage for input variations from 105 - 125 v ac; load regulation is less than 0.1% change in output voltage for load variations from zero to full load. Ripple and noise is less than 5 mv rms and output impedance is less than 1 Ω from dc to 100 kc.

11,243 POWER SUPPLY (Kepco Inc., 131-38 Sanford Ave., Flushing 52, N.Y.)

A low-cost, transistorized, voltage/current regulated power supply (Model ABC 40 - 0.5 M) is announced. The device features constant current operation to 0.5 per cent for 105 - 125 v ac line change at any selected current value within its regulated output range of 10 ma to 500 ma. Output voltage varies from 0 to 40 v as required to maintain constancy. Other features include adjustable current limiting, overload protection, and built-in provision for remote programming and error-sensing.

11,244 SERVO AMPLIFIER (Industrial Control Co., Central Ave. at Pinelawn, Farmingdale, L.I., N.Y.)

A high-power, four-transistor, 400 cps miniaturized servo amplifier (Model 803-A) designed to drive two phase servo motors with shaft outputs to 50 watts is announced. It operates directly from the 117 v 400 cps line, and will accept both dc and ac signal inputs. Featured is a specially designed forced-air heat exchanger that exhausts the internal dissipation into the ambient air. Maximum electrical output is 130 watts, operating ambient -55° to +55°C, size 6 x 5 3/9 x 4 in, and weight 7.5 pounds.

11,245 TUNING FORK OSCILLATOR (Solid State Electronics Co., 15321 Rayen St., Sepulveda, Calif.)

The model TF-120, a completely solid state silicon transistor crystal and heater controlled sine wave oscillator is announced. Performing at low frequencies as a secondary frequency standard, this tuning fork controlled oscillator obviates the need for elaborate methods of frequency division. The tuning fork assembly is housed in a hermetically sealed enclosure filled with inert gas, while the unit itself is solidly encapsulated in lock-foam.

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